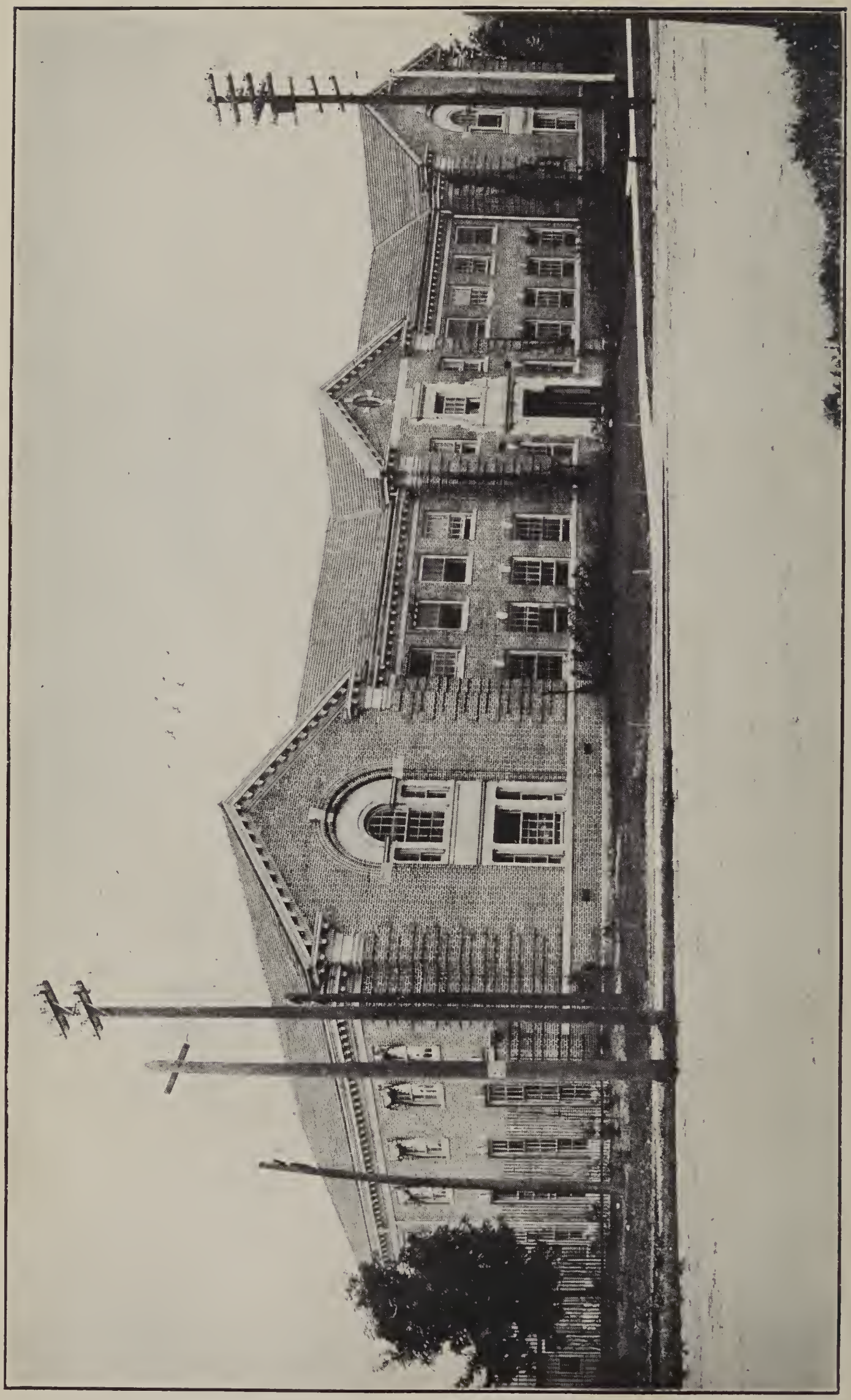
PLATE I.



FOREST PRODUCTS LABORATORY, MADISON, WIS.

Issued March 11, 1913.

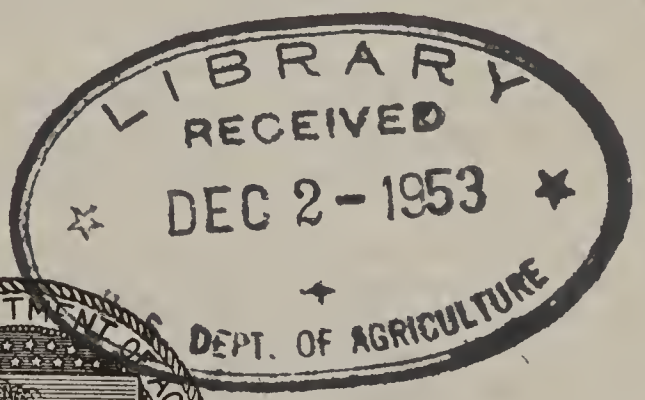
U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.
HENRY S. GRAVES, Forester.

REVIEW

OF

FOREST SERVICE INVESTIGATIONS.

VOLUME I.



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FOREST SERVICE.

HENRY S. GRAVES, *Forester.*
ALBERT F. POTTER, *Associate Forester.*
HERBERT A. SMITH, *Editor.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., October 11, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Review of Forest Service Investigations," Volume I, and to recommend its publication.

Full development of the National Forests as productive resources involves extensive research work. Technical forestry is a branch of scientific agriculture and can be successfully applied only as practice is based on accurate knowledge. From the wide range of conditions which the National Forests present, the Forest Service has found it necessary to adopt a comprehensive plan of studies for the systematic investigation of many problems.

As these studies progress it is important that there should be some means of keeping the entire technical force informed concerning the results obtained, of providing for free discussion of methods and tentative conclusions, and of making possible such immediate modifications of existing practice as the discoveries made may warrant. The Review of Forest Service Investigations has been planned to meet this end. Successive numbers will be issued as the material accumulated permits. The Review will contain progress reports on uncompleted investigations and final reports on minor experiments which do not justify separate publication.

It will follow necessarily from the purpose which the Review is designed to serve that a certain freedom will be given for the expression of individual opinion. In other words, the Review will deal largely with matters on which the Forest Service can not yet speak authoritatively; the views presented are for professional consideration, on their merits, and their publication by no means implies that full responsibility for them is assumed by the Forest Service.

While the Review is published primarily for use within the Forest Service, it will unquestionably be valuable also to professional foresters who are not in the employ of the Government and to investigators in closely allied fields of work. A limited provision for public distribution to such persons is therefore recommended. The Review is, however, of professional, not of popular, character.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

LABORATORIES AND FOREST EXPERIMENT STATIONS OF THE FOREST SERVICE.

Forest Products Laboratory (in cooperation with the University of Wisconsin), Madison, Wis.
Ground Wood Laboratory, Wausau, Wis.
Wood Testing Laboratory (in cooperation with the University of Washington), Seattle, Wash.
Priest River Experiment Station, on the Kaniksu National Forest, Priest River, Idaho.
Cloquet Experiment Station (in cooperation with the University of Minnesota), Cloquet, Minn.
Fremont Experiment Station, on the Pike National Forest, Manitou, Colo.
Wagon Wheel Gap Experiment Station, on the Rio Grande National Forest, Wagon Wheel Gap, Colo.
Fort Valley Experiment Station, on the Coconino National Forest, Flagstaff, Ariz.
Utah Experiment Station, on the Manti National Forest, Ephraim, Utah.
Feather River Experiment Station, on the Plumas National Forest, Quincy, Cal.
Seed Testing Laboratory and Willow Holt Station, Office of Silvics, Arlington Farm, Washington, D. C.
Dendrological Laboratory, Office of Dendrologist, Washington, D. C.

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ILLUSTRATIONS.

REVIEW OF FOREST SERVICE INVESTIGATIONS—Volume I.

OBJECT OF THE PUBLICATION.

The investigative work of the Forest Service has greatly broadened within the last few years. A large and well-equipped laboratory in forest products is now maintained at Madison, Wis., in cooperation with the University of Wisconsin, with supplemental studies in the East and West. Three Forest experiment stations in the central and southern Rockies, one in the Sierras, and one in northwestern Idaho have been established on National Forests for intensive study of silvicultural problems. In addition one experiment station is being maintained at Cloquet, Minn., in cooperation with the University of Minnesota. Aside from these stations an enormous amount of investigative work has been inaugurated in reforestation, growth, yield, various methods of cutting, and other fundamental aspects of silviculture in every part of the country. An office of grazing studies has been established. Its work, already begun at a grazing experiment station in Utah and on several Forests, is being rapidly extended.

The growth of the scientific work of the Service is a natural response to increasing demand for thorough scientific facts upon which to base the proper handling of the forest and range. The development of the science of forestry and its application to the management of the forest must go on simultaneously. But meager data are available in this country upon which to base scientific forest management and utilization, as the practice and science of forestry developed in the older countries are of little direct value because of differences in species and in climatic and economic conditions. It is very important, therefore, that the results of investigative work be made known, as soon as they are obtained, to the practicing forester, timber owner and user, and to the profession as a whole. The results of the more important investigations of the Forest Service are sooner or later issued as separate publications and become generally available. The completion of many investigations, however, often requires several years, during which very little is known of their progress. The results of minor investigations and observations, which in themselves are not of broad enough scope or suffi-

ciently conclusive to warrant separate publications, yet in the aggregate are of inestimable value, are frequently lost to foresters outside the locality where they were secured.

To provide a means for making the results of such investigations systematically available, as well as the progress attained in the major investigations, a series of publications, to be known as the "Review of Forest Service Investigations," has been undertaken. The object of these publications, of which this is the first, is to give periodically a comprehensive review of the character and progress primarily of the investigative work of the Forest Service, and to some extent also of the various States and forest schools. It will aim to keep all of the men engaged upon investigative work in touch with each other. It will give them the fresh results of each study as it develops. It will be primarily for the interest and benefit of all the investigators in the Service, in all lines of its work, as a cumulative medium for interchange of scientific data and ideas. It is designed to improve investigative methods, avoid duplication, and stimulate interest in research work.

The Review of Forest Service Investigations is issued at intervals as sufficient material accumulates. It is designed to furnish periodically a resumé of the character and progress of the investigative work conducted by the Forest Service. Each issue will contain brief accounts of the progress made on the more important studies whose completion may require several years, and more detailed reports of minor projects whose publication in separate form is inadvisable. Similar material furnished by State foresters will be published from time to time.

It is the purpose of this Review to keep all of the men engaged upon investigative work in touch with each other. The fresh result of each study as it develops will be reported, and a medium furnished for the interchange of scientific data and ideas.

The Review deals largely with matters on which the Forest Service can not yet speak authoritatively and the publication of the views presented does not imply that the Forest Service assumes full responsibility for them.

ORGANIZATION AND SCOPE OF INVESTIGATIVE WORK.

The broad scope of the investigations now carried on by the Forest Service called for an organization which would unify the various scientific activities, prevent duplication, coordinate and correlate all studies, and consider carefully all plans to make sure that the most important problems are attacked in the right way and that all the available information and facilities of the Service are utilized. Such an organization was put into effect in January, 1912, in the form of district and central investigative committees. The creation

of these committees marks a progressive step in the development of the investigative work of the Service. It is a recognition of the old principle that several heads are better than one in perfecting plans which call for the best the Service has in scientific attainments and experience in research.

The plan adopted and at present in effect is in general as follows:

In each of the districts, into which the territory occupied by the National Forests is divided, there is a district investigative committee, consisting usually of one representative of each of the major lines of investigation conducted in the district and one supervisor of technical training. Aside from the supervisor the members of the district committees, as far as practicable, are men engaged primarily upon investigative work.

On or before December 15 of each year each district office chief submits to the district committee an annual program of investigative work, under the direction of his office, this program covering:

1. Projects completed during the past calendar year.

2. Program for ensuing calendar year, consisting of (*a*) Incomplete projects upon which work will be continued; (*b*) New projects proposed.

The programs of work submitted by the respective officers are then reviewed by the district committee, special consideration being given to (1) the value of each project under way or proposed; (2) the scope of each project and whether it should be limited or extended; and (3) possible correlation with lines of investigative work in progress or proposed by other offices.

The district committee then prepares a program of investigative work for the district with recommendations regarding the policy to be followed. This program is then carefully considered by the district forester and office chiefs in consultation with the committee. The annual program of work for the district in final form is approved by the district forester. Copies of this program are then submitted to the Forester as a part of the annual investigative report for the district.

The complete programs submitted by the districts are referred to the branch chiefs of the Forest Service in Washington who review and correlate all the work proposed under the direction of each branch. Each branch chief then submits a complete program of work for his branch to the central investigative committee, which consists of three members representing respectively the branches of Silviculture, Products, and Grazing. The branch programs are reviewed by the central investigative committee, which prepares an annual program of work and outlines the investigative policy for the entire Service. This program is then considered by the Forester in consultation with the branch chiefs and central committee.

When finally approved the necessary administrative action is taken by each branch to put the program and policy into effect.

Projects included in the approved program are assigned by the branch chiefs to the various units of organization, the proper executive officer in each unit assigning the project to the member of the Service who will be in charge of the investigation. The officer in charge of each project then prepares—

1. A preliminary report reviewing the results of other investigations bearing upon the subject and the main features of the work which should be undertaken.

2. A working plan which states specifically (*a*) the purpose and scope of the proposed investigation, (*b*) the methods to be followed, and (*c*) the estimated cost.

At the discretion of the proper executive officer the preliminary report and working plan may be combined. The preliminary report and working plan for the project are approved by the branch chief or such executive in the branch or in the field as he designates. The work is then carried on in accordance with the working plan, which can not be departed from without the concurrence of the approving officer.

This plan of control applies only to the more important lines of investigation which are to be conducted and does not govern minor investigations or observations conducted by forest officers and others in connection with administrative duties where the use of additional funds is not required. Such minor investigations, however, are directed so far as practicable by the district committees through the office chiefs and are thus correlated with the regular investigative work.

DESCRIPTION OF THE DIFFERENT LINES OF INVESTIGATION.

The investigations carried on by the Forest Service fall naturally into four large divisions: Dendrology, Grazing, Products, and Silviculture.

DENDROLOGY.

Dendrological studies aim to secure information concerning the distinguishing characters and the geographic distribution of North American trees and shrubs. They also include investigations of the gross and microscopic structure of the woods of the more important North American and foreign timber trees as means for identification. These studies are carried on by the Dendrologist and his assistants located in Washington, D. C., with such help from the National Forest officers as they may give by collecting tree specimens and reporting the occurrence of species, particularly outside of their supposed range. One important purpose of dendrological studies

is the preparation for publication of popular works describing and illustrating North American trees, woods, and shrubs.

In accordance with the chief aim of these dendrological studies, they are divided under the following heads:

FOREST-DISTRIBUTION STUDIES.

The object of these studies is to determine the geographic distribution of North American forest trees and shrubs and their distinguishing characters. All available range records are plotted on folio maps, and exact references are preserved of the source of this information, which is obtained largely from unpublished records of the Service, as well as from current literature, notes collected by examining the different herbaria in the United States, and from data accompanying tree specimens collected by the Dendrologist and his assistants or other forest officers in the field. These folio maps, revised and corrected as often as new information is secured, are available for reference, and from them distribution data are furnished for all publications of the Service requiring such information, particularly the series of works being issued dealing specially with the identification and range of North American trees and shrubs.

A part of these studies is the maintenance of a forest herbarium in the Washington office. Specimens for this collection are obtained by the Dendrologist and his assistants, by exchanges, and with the assistance of the National Forest officers in the field. This material, systematically classified for reference, is used in the studies of forest floras, in the identification of trees and shrubs, and in making original illustrations of species described.

WOOD-STRUCTURE STUDIES.

The object of these studies is to secure reliable information for distinguishing different woods by their structure. There are many inferior species which in general superficial appearance closely resemble better kinds of wood and for which they are often substituted. It is of particular importance for the benefit of wood consumers, as well as of scientific interest, to be able accurately to identify different species of woods by their gross and anatomical structure. A fully equipped laboratory is maintained in Washington for the purpose of preparing microscopic sections of woods which are used as a reference collection in the identification of wood specimens and from which illustrations are made for publications issued describing the distinguishing characters of woods.

The number of foreign woods on the American market is now very great and is gradually increasing. Both the dealers in imported timbers and those who use them are in need of and seeking reliable

information in regard to these new and unfamiliar kinds. Many different species of foreign woods are being sold in this country under the familiar trade names of well-known sorts which makes it necessary, in the interest of wood users, to determine the true identity of such imported material and the source from which it comes. For this reason it became necessary to extend to foreign woods also the study of structure as a means of identification. American capital is now being invested in tropical American timber lands, and there is a growing demand for accurate knowledge regarding the identity, uses, and properties of tropical woods.

GRAZING.

The aim of the grazing investigations is to secure thorough scientific information leading to—

1. The production of the maximum value of forage crop.
2. The utilization of timber areas and areas above timber line by grazing without jeopardizing the chances of reforestation and watershed protection further than is justified by the comparative merits of the resources at stake.
3. Securing the greatest grazing efficiency per unit area in utilizing the forage available for use.

Any increase in the value of the forage crop produced must be brought about by (1) successfully seeding range to cultivated forage plants, seed of which can be obtained at a cost which justifies its use; (2) by so managing the grazing of the range as to secure the natural seeding of the most valuable native forage plants in each locality or by developing these valuable native species under cultivation so that seed can be produced at a cost not prohibitive to distribution on the range. The investigations along these lines fall under three headings:

Artificial reseeding.

Natural reseeding.

Distribution and economic importance of forage plants.

All the investigations carried on for the purpose of deciding what portion of the forage crop can be used without undue injury to forest and watershed fall under the one heading:

Forest protection (grazing).

The investigations for the purpose of securing data which will aid in getting the greatest grazing efficiency out of the forage available for use cover the following field:

Methods of handling stock.

Development of stock-watering places.

Poisonous-plant investigations.

The grazing projects comprise both intensive experimental studies and studies initiated primarily to put the results of intensive studies

into application in the actual management of the range. The intensive investigations are concentrated at the Utah Experiment Station on the Manti National Forest and on several Forests where there are the best opportunities for studying the problems most important, at present the Coconino, Shasta, and Payette Forests. Less intensive investigations leading to better control of grazing are necessarily carried on in connection with the administration of the range on a number of Forests where particular problems arise.

ARTIFICIAL RESEEDING.

The aim of studies in artificial reseeding is to determine means of restoring overgrazed areas and improving the quality of the forage by artificial reseeding with cultivated plants. But a comparatively small acreage of National Forest range is adapted to the growth of the forage plants for which seed is available, due to excessive altitude, poor soil, drought, or other conditions. In order to carry on successfully artificial reseeding of the range, it is important to find out (1) the lands where seeding to cultivated species is economically possible as determined by altitude, exposure, soil, moisture, and native vegetation; (2) the species best adapted to any given set of conditions; (3) the time to sow, the cultural methods which should be used; and (4) the necessary protection against grazing. In addition, the most promising native species are being tried under cultivation experimentally to determine the possibility of their use in artificial reseeding.

NATURAL RESEEDING.

Investigations of this character aim to determine the possibilities of naturally reseeding depleted lands that still have a part of the native vegetation, and to devise systems of grazing management which will permit of the regeneration of the lands without a loss of forage values. These investigations are both intensive and extensive. The intensive studies aim to find out the important forage plants, determine their absolute requirements of growth and reproduction, and with these data as a basis, perfect a plan of grazing management which will allow the plants to reseed naturally often enough to keep the range in maximum condition—this with the least possible loss of forage. The extensive studies aim to put the data collected from the intensive studies on a practical basis by demonstration application to range management.

DISTRIBUTION AND ECONOMIC IMPORTANCE OF FORAGE PLANTS.

The aim of this work is to ascertain the species of plants which make up the forage crop as well as the objectionable and worthless plants on each Forest range, and to determine the forage value,

growth requirements, seasons of growth, time of seed maturity, and class of stock for which each is best adapted. With a thorough knowledge on these points regarding the plants which make up the forage crop on each Forest, there will be greater possibility of developing a plan of grazing management which will sufficiently recognize the growth requirements of the vegetation to maintain a maximum yield without unnecessary loss of forage by nonuse.

FOREST PROTECTION (GRAZING).

The aim of studies along this line is to collect information which will result in a decision as to the proper relation of grazing to National Forest management. The work comprises (1) studies to determine the effect, both detrimental and beneficial, of grazing upon tree reproduction and the possibility of eliminating damage or increasing the beneficial effect by changes in grazing management; (2) studies to determine the influence of grazing upon "run-off" and erosion; (3) studies to determine the influence of grazing as a protection against fire. The projects under (1) and (2) must necessarily be intensive and will be carried on at the Utah Experiment Station or on a few selected Forests.

METHODS OF HANDLING STOCK.

Investigations of this character aim at eliminating, so far as practicable, any waste of forage in utilization of the range by reducing to a minimum the loss of forage due to trampling and by reducing the damage that comes from interfering with natural processes of revegetation and damage to tree growth and watersheds. The work covers studies to determine: The most satisfactory number of sheep to be run in one band, considering the welfare of the range and the sheep and the interests of the sheep owner; the best method of herding or handling, salting, bedding, and watering the sheep; methods of handling cattle, and other grazing animals (swine, horses, goats).

DEVELOPMENT OF STOCK-WATERING PLACES.

Without an adequate distribution of water for the stock on the range, it is frequently impracticable to adopt a system of grazing management which will place on a range the class of stock to which it is best adapted at the time when it should be utilized, and to plan the handling of the stock so as to secure complete utilization without waste of forage. The studies along this line aim to secure information upon which to base a decision as to the necessary distribution and capacity of watering places under a given set of topographic, climatic, and forage conditions; and how best to develop watering places from different sources of water supply.

POISONOUS PLANT INVESTIGATIONS.

The scientific data on poisonous plants are very largely collected by the Bureau of Plant Industry. The Forest Service is cooperating in working out the abundance, distribution, and seasons of growth in various localities of the species of plants poisonous to stock.

PRODUCTS.

The aim of the investigations conducted by Products is to secure authentic information regarding the properties and suitability for different purposes of various species and kinds of forest products. Such information is essential to increase the efficiency of the methods at present in use in the production and utilization of forest products, and is necessary for the most economical management of the National Forests.

In accordance with the general policy of centralizing the investigative work at specific points, practically all of the products studies are conducted at a few definite stations. The Forest Products Laboratory at Madison, Wis., is the headquarters at which is conducted the great bulk of the work. This laboratory, which is maintained in cooperation with the University of Wisconsin, is well equipped for conducting most of the lines of work discussed later. Laboratories are also maintained at Wausau, Wis., where the groundwood pulp investigations are all conducted, and at Seattle, Wash., where certain tests on the mechanical properties of woods are carried on. District stations are also permanently established at Washington, D. C., San Francisco, Cal., and Portland, Oreg., and certain more general investigations are conducted from these points.

The investigative work falls into four major divisions, with a number of subdivisions, as follows:

A. Mechanical and Physical Properties and Structure of Woods.
- Mechanical properties.
  - Tests on small specimens free from defects.
  - Tests on structural timbers.
  - Tests on manufactured articles.
  - Effect of preservative treatment, moisture, etc.
- Physical properties.
  - Fundamental properties.
  - Conditioning experiments.
  - General.
- Relation of structure to properties.

B. Wood Preservation.
- Preservatives.
  - General.
  - Physical and chemical properties.
  - Toxicity.
  - Effect on strength of wood.
  - Inflammability.
  - Ease of injection into wood.

B. Wood Preservation—Continued.
  Processes.
    Commercially established.
    New or proposed.
    Effect of varying conditions during treatment.
  Suitability of species.
    Resistance to impregnation with preservatives.
    Resistance to decay.
    Preparation for treatment.
  Cooperative field work and service tests.
C. Derived Products.
  Pulp and paper.
    Mechanical or grinding processes.
    Chemical processes.
  Wood distillation.
    Hardwoods.
    Resinous woods.
  Naval stores, or turpentine and rosin.
  Miscellaneous.
    Production of ethyl alcohol.
    Production of tannins.
    Production of gas from wood waste.
    Production of essential oils from leaves, twigs, etc.
    Chemical composition of various woods.
D. Statistical Studies.
  Annual production of forest products.
  Study of uses of woods (by States, industries, and species).
  Lumber prices.
  Miscellaneous.

MECHANICAL PROPERTIES OF WOOD.

These tests are primarily for the purpose of accumulating reliable information on the mechanical properties of various species and forms of timber. The results are of value to all engineers, manufacturers, and other users of wood in enabling them to employ the various species and forms most advantageously, and frequently to substitute less well-known species for those which have been commonly used but are now becoming scarce. The nature of the investigations is such that they may be classified under the following headings:

Tests on Small Specimens Free from Defects.

The purpose and general nature of these investigations are as follows:

(*a*) To establish scales by means of which it will be possible to compare directly the bending strength, compressive strength, shearing, stiffness, toughness, hardness, cleavability, coefficient of shrinkage, and specific gravity or dry weight of the commercial timbers of the United States. Such scales will make it easier for users to select substitutes for species which are becoming scarce.

(*b*) To correlate the properties listed above with the rate of growth, the position of the specimen in the tree, the physical characteristics of the tree, and the locality and conditions under which the tree grew. Such analyses are primarily for the use of a forester if the conditions in this country ever permit the selection of material in the woods with respect to its suitability for certain specific purposes.

Tests on Structural Timbers.

The purpose of these investigations is as follows:

(*a*) To supply engineers and architects with data on which to base moduli for use in the design of structures built of timber.

(*b*) To correlate the results of the tests with the physical characteristics of the timber and with the character and location of defects in order to establish a more correct basis for the grading of large timbers according to their mechanical properties.

(*c*) To establish a relation between results obtained from large timbers containing defects and those obtained from small specimens free from defects, so that the strength of structural timbers may be estimated from tests on small pieces.

Tests on Manufactured Articles.

This series includes tests on axles, spokes, cross-arms, poles, and other manufactured articles. They constitute, however, a minor part of the investigative work and are made primarily for the purpose of demonstrating the fitness of a substitute species or a lower grade of material for specific uses.

Effect of Preservative Treatments, Moisture, Etc.

This series of tests is for the purpose of studying the effect of moisture, preservative treatments, methods of seasoning, fireproofing, etc., upon the mechanical properties of wood. Both structural forms and small specimens free from defects are used in the various studies, the form and character of the specimens in each case being determined by the nature of the problem.

PHYSICAL PROPERTIES OF WOOD.

From the foregoing brief outline of the purpose and scope of the investigations on the mechanical properties it can readily be seen that they are closely connected with similar investigations on the physical properties of wood. The work falls into the following divisions:

Fundamental Properties.

A knowledge of the fundamental physical properties of wood in general and of the various species individually is essential to the most efficient utilization of the material. Not only is such knowledge

of prime importance in connection with studies on the structural and mechanical properties, but it is especially necessary for the most successful conducting of investigations relating to wood preservation and some other wood-using industries. The several lines of investigation cover studies of the thermal properties, penetrability to liquids and gases, hygroscopicity, density of wood substance, etc.

Conditioning Experiments.

These experiments relate primarily to the application of the knowledge of the structure, mechanical properties, and fundamental physical properties of wood in its preparation and handling for commercial uses, and consist largely of investigations into seasoning and drying. The results will be of value to all engaged in the manufacture and utilization of wood products, such as lumber, structural timber, ties, poles, wagons and vehicles, implements, and furniture. In the manufacture and handling of such products much money and time are spent in seasoning the wood, and often a considerable proportion of the raw material is lost or damaged as a result of improper seasoning. Information on the fundamental principles of drying lumber is needed in order to improve these conditions. The investigations logically fall into three divisions, as follows:

(*a*) *Air seasoning.*—The importance of this work is evident when it is considered that it affects the entire lumbering and wood-manufacturing industries. Not only is seasoning essential in the production and utilization of a large proportion of the products, but much material inadvertently becomes seasoned as a result of enforced storage of raw material or finished product. Furthermore, it is necessary in practically all cases to air season material prior to kiln drying by the methods in general commercial use. In spite of the importance of the subject, however, and the well-known advantages of properly seasoned timber, such as increased strength, durability, and penetrability to liquids, much material is annually damaged by checking, decay, sap staining, and other agencies, with a corresponding financial loss.

It is the purpose of the investigations to assist in bettering these conditions by securing data on the proper methods of piling and the time required to air season various forms and species in various localities. The results are of especial value to the Forest Service in the work under way on wood preservation, kiln drying, and mechanical properties of wood.

(*b*) *Kiln drying.*—The time required to air season wood properly is so great that artificial methods of drying are being almost universally applied. Unfortunately, however, methods do not yet permit of wood being kiln dried without first being seasoned at least to a partial extent. The big problem which confronts the users of wood is to

FIG. 1.—MACHINES FOR TESTING THE MECHANICAL PROPERTIES OF WOODS, FOREST PRODUCTS LABORATORY.

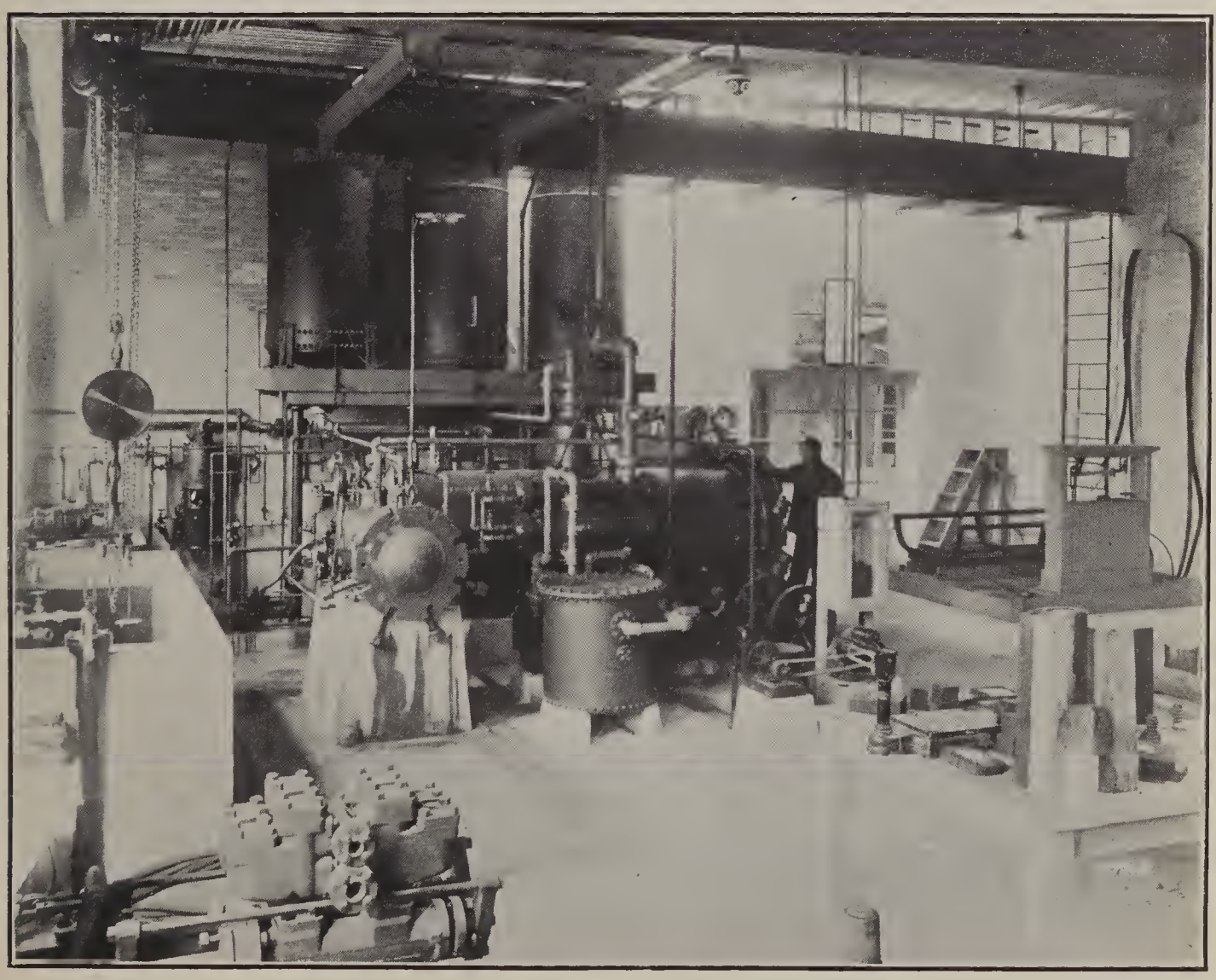

FIG. 2.—EQUIPMENT FOR WOOD PRESERVATION EXPERIMENTS, FOREST PRODUCTS LABORATORY.

season it in the shortest possible time. All methods at present in use are more or less imperfect, and it is conservatively estimated that at least 10 per cent of the material dried in kilns is ruined or greatly lowered in value by excessive checking, warping, honeycombing, etc. To study the fundamental principles of drying in kilns with a view to finding means of overcoming the present difficulties is one of the aims of these investigations.

(*c*) *High temperature and pressure treatments.*—Very little is known concerning the behavior of wood when subjected to high temperatures and pressures or to various conditions of the surrounding medium. Preliminary experiments indicate that certain of the physical and mechanical properties, such as density, strength, hardness, and hygroscopicity, can be altered by such treatments. The aim of these investigations is to find methods of altering the properties of the less valuable woods so as to increase their field of use.

General Studies.

These investigations are so varied in nature that they can not be classified under any specific heading.

RELATION OF STRUCTURE TO PROPERTIES.

These investigations aim to find the effect of different kinds of structure on the mechanical and physical properties of woods and to show the structure best adapted for certain specific uses. The work may lead to several methods of grouping, based on the use intended and independent of the botanical classification. The study of wood elements and fibers as found in pulp forms an important phase of the work, as does also the effect of structure on the penetrance of preservatives.

WOOD PRESERVATION.

These investigations deal with the protection or preservation of wood from destruction by decay, fire, abrasion, and insects. Of these, decay is by far the most important, and it is with this that the investigations are mostly concerned.

The importance of the investigations are illustrated by the fact that over 100,000,000 cubic feet of wood were treated in 1910 with preservatives to protect them from decay, which is an increase of over 500 per cent of that treated during 1904. Although it can be appreciated at once that the industry is rapidly growing and becoming established in this country, there are still many points on which further and more definite information is required in order that the most efficient methods may be employed. The nature of the investigations can best be discussed separately under the following classifications:

PRESERVATIVES.

GENERAL.

The cost of preservatives amounts to from 50 to 90 per cent of the total cost of treatment, and the ultimate success of any treatment is largely dependent upon the preservative used. Many substances have been tried as preservatives, and a variety of opinions exist as to what preservative will give the greatest efficiency under different conditions.

It is the purpose of the work to secure authentic information on the relative efficiency of various preservatives which are now being used commercially or which give promise of success in preventing decay. The work may be classed into investigations of oils, metallic salts, and other materials, their efficiency depending to a greater or less extent upon the following points:

PHYSICAL AND CHEMICAL PROPERTIES.

This is the first step in studying the efficiency of any preservative. It may frequently happen that a determination of these properties is immediately sufficient to prove the product unsatisfactory.

TOXICITY.

The success of many preservatives depends entirely upon their antiseptic or toxic properties, or, in other words, upon their poisonous effect upon decay-producing organisms, insects, or marine borers. This is true of all the metallic salts and in a large measure of many of the other preservatives used.

EFFECT ON STRENGTH OF WOOD.

However efficient a preservative may be in retarding decay, it is evidently essential for the great majority of cases that the strength of wood should not be seriously affected by its injection.

INFLAMMABILITY.

There are many instances where a preservative might be advantageously used were it not for the danger of increasing the inflammability of the timber. This is especially true in such cases as mine timbers, where the wet conditions are frequently adverse to the use of metallic salts and where the use of creosote or other oils would be effective were it not for the possible increased danger from fire. Furthermore, the protection of wood against fire is an important field in the wood-preservation work, since more stringent rules are everywhere being put into effect regarding the use of inflammable material in buildings.

EASE OF INJECTION INTO WOOD.

This is an important aspect in determining the efficiency of a preservative, since it is evident that its efficiency is impaired if it can not be forced into the wood with comparative ease.

Processes.

Closely related to the work on preservatives is the investigative work on processes. However efficient a preservative may be in itself, it is important that it be injected into the wood in the most efficient and economical manner. The work covers investigations of the relative efficiency of the various processes in commercial use, of proposed or new processes, and of the effect of varying conditions during treatment. The intention is to determine the effect of each step in various established and proposed processes upon the impregnation of the wood and its condition after treatment.

Suitability of Species.

Closely related to the work on preservatives and processes is the determination of the suitability of various species for treatment. One of the chief aims of such work is to increase the use of the cheaper and less durable woods, of which there is a plentiful supply, in place of the more costly and naturally durable woods which are more generally used. Information on the relative permeability of various woods will be of value to the consumer in selecting his material and of special value to the Forest Service in disposing of many species on the National Forests for which at present there is no great demand. The work involves investigations to determine the resistance of woods to impregnation with preservatives, their relative resistance to decay, and the methods necessary to satisfactorily prepare them for treatment.

Cooperative Field Work and Service Tests.

Owing to the comparatively recent development of wood preservation in this country, one portion of the work on this subject consists of cooperative field work and of service tests. The final test of any preservative or process applied to any species or form of material is to place such material under actual conditions of service and note the results.

PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER.

The investigations on derived products are divided according to the product under consideration, as follows:

Pulp and Paper.

The manufacture of pulp and paper is a well-established industry which uses wood and rags as raw material and whose products are in large demand. Its magnitude as a wood-using industry is shown by the fact that in 1909 over 4,000,000 cords of wood were consumed. The cost for this wood alone was over $33,000,000. The annual

consumption of wood for pulp products increased over 100 per cent from 1900 to 1909, while its cost increased over 240 per cent. Since 60 per cent of the wood used for pulp in 1909 was spruce and 15 per cent hemlock, the importance of investigating the value for pulp of species at present little used and of various forms of wood waste is evident. Studies of methods to increase the efficiency of established processes are also needed.

The pulp investigations may be classified as follows:

MECHANICAL OR GRINDING PROCESSES.

So far as the immediate needs of the paper trade are concerned, this work is of the greatest importance. Much of the cheaper paper, such as news print, is made from pulp produced in this way. At the present time practically the entire supply of ground-wood pulp is produced from spruce, and the diminishing supply and increasing price of this species makes the search for satisfactory substitutes of live interest to pulp manufacturers. A study of the details of the processes used in making different kinds of pulp is also carried on with a view to determining the most efficient methods of production.

CHEMICAL PROCESSES.

It is by chemical processes that pulp for use in the finer and stronger grades of paper is produced, and although a greater variety of woods are used than for the ground-wood pulp the fundamental problem confronting the industry here also is the supply of raw material. In 1909 over 85 per cent of the wood consumed consisted of spruce, hemlock, poplar, and balsam, and it is the prime aim of the investigative work to determine the relative suitability of other available species and forms of material.

In studying the suitability of the various woods, their adaptability for the different established processes must be considered. This involves a thorough knowledge of the various processes and of the effect of varying certain conditions on the final product. The work on species and processes, therefore, is closely connected and may be classified into:

(*a*) Studies with the soda process, which is a well-established process suited for either deciduous or highly resinous woods;

(*b*) Studies with the sulphite process, which is the process now most extensively used in this country and is especially adapted for the not too resinous conifers and for the production of pulps where a very white natural color is desired;

(*c*) Studies with the sulphate process, which, although used only to a limited extent in this country at present, gives promise of becoming of more importance especially for the manufacture of pulps from the southern pines and more resinous woods.

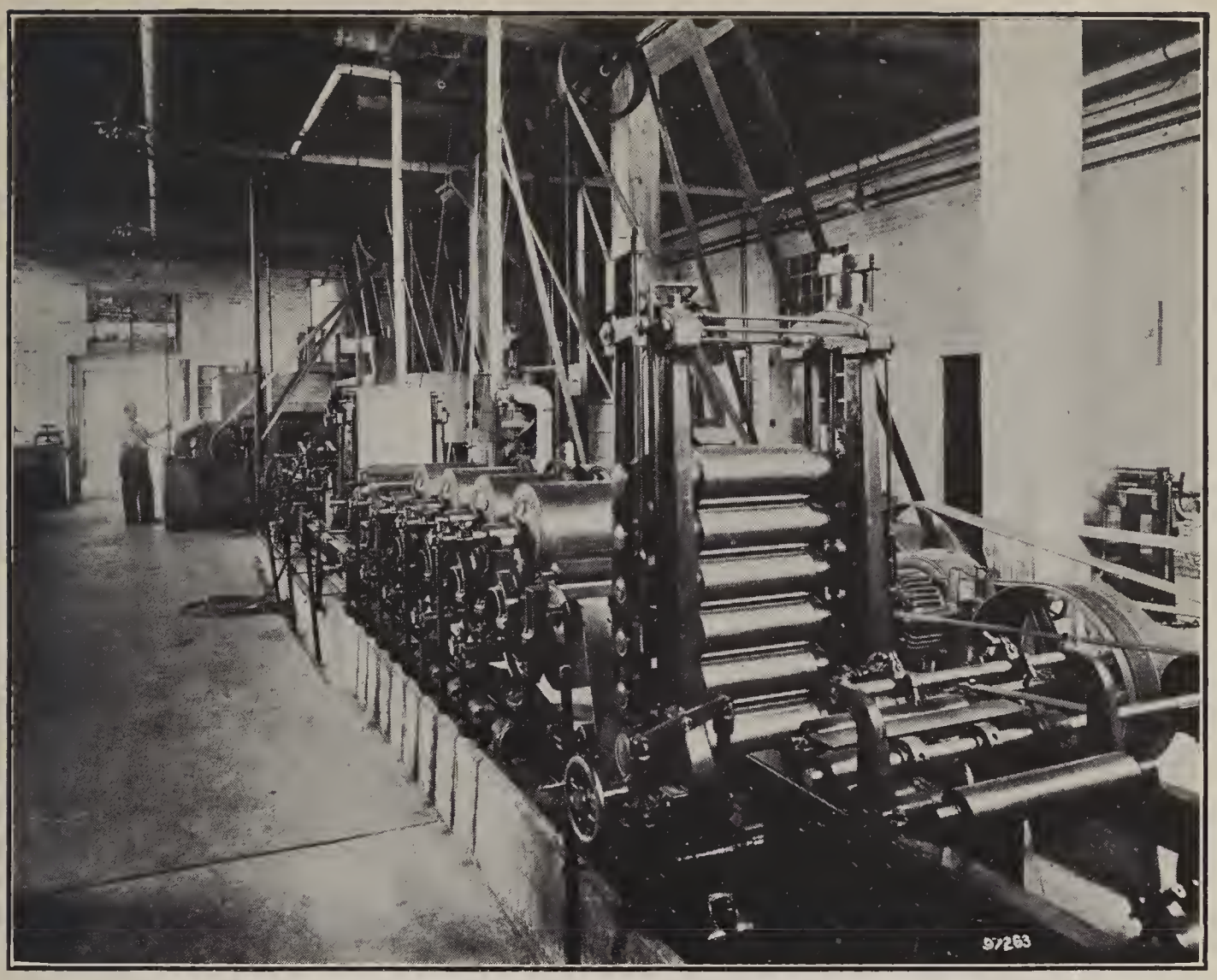

FIG. 1.—PAPER MACHINE, FOREST PRODUCTS LABORATORY.

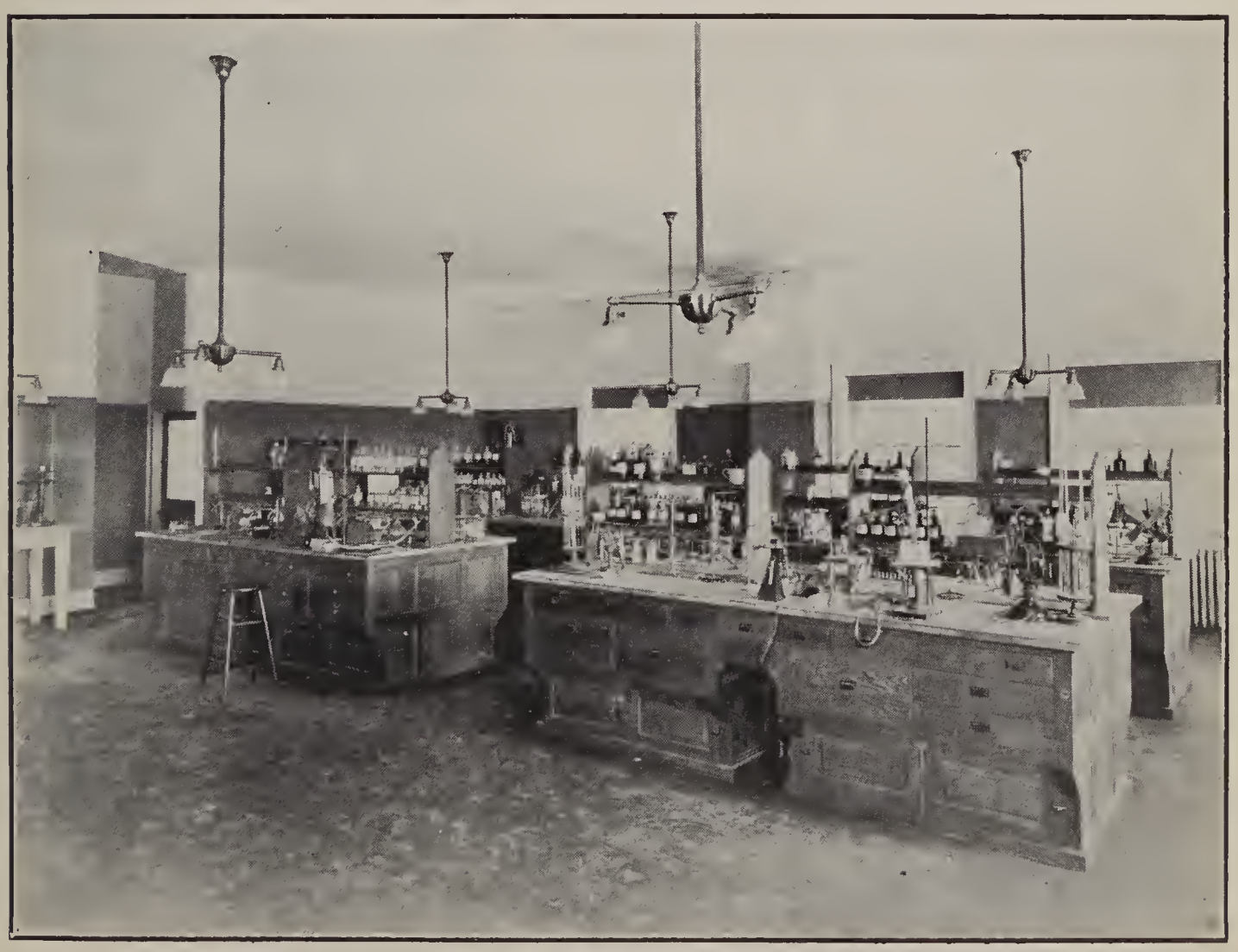

FIG. 2.—EQUIPMENT FOR ANALYZING AND TESTING PRESERVATIVES, TURPENTINE, PRODUCTS OF WOOD DISTILLATION, ETC., FOREST PRODUCTS LABORATORY.

Wood Distillation.

Wood distillation is already a fairly well-established industry, consisting of two distinct branches—hardwood distillation and resinous wood distillation. Both branches depend on waste wood to a large extent for raw material so that the investigations consist (1) of a study of new species which may be found suitable; (2) of the development of more efficient methods of production and refining; and (3) of the determination of the properties of distillation products not readily marketable at present.

The nature of the two branches of the work is as follows:

HARDWOODS.

This is an established industry with fairly well-standardized processes. Two of the main products—acetate of lime and wood alcohol—are regularly quoted market articles. The third, charcoal, is usually sold to iron furnaces or in other local markets for fuel. In many of the commercial plants wood cut especially for the purpose is used, while others are operated on sawmill waste, so that only that part of the tree not suitable for lumber is used for distillation. Small-sized material, such as sawdust and shavings, is not practicable, since the charcoal produced is so fine that it is difficult to cool and handle, and the small size of the material makes it such a poor conductor of heat that it is impossible to char it satisfactorily in the ordinary forms of apparatus.

The species most extensively used in commercial work are birch, beech, and maple. The amount of valuable products that can be obtained from these woods is comparatively well known, but very little information is available for other species. The purpose of the investigations, therefore, is primarily to determine the suitability of other species for distillation purposes.

RESINOUS WOODS.

This is a comparatively recent industry in this country for which standard methods have not yet been developed. Some of the products also have not yet become standard market articles. The investigations cover the following fields:

(*a*) *Destructive distillation.*—In selecting material for this purpose the governing factor is the amount of resin or pitch present in the wood, and since this resin content is variable for different trees of the same species, and even in different parts of the same tree, it is usually necessary to select the wood in order to obtain a material sufficiently rich for distillation. The largest portion of material at present used consists of "lightwood" from longleaf pine. Stump wood from the same species has been used also to some extent; but the

"lightwood" is commonly used, since the stump wood is more difficult to collect and prepare for distillation.

(*b*) *Steam distillation.*—There is another form of material, such as the average run of sawmill waste, sawdust, and slabs from longleaf pine, which on account of its comparatively small resin content can not be used economically for destructive distillation, and apparently the only process which is applicable to this class of material is the simple and more rapid steam-distillation process, which recovers only the volatile oils originally present as such in the wood.

It is the purpose of these investigations (1) to standardize methods of distillation for various species and classes of material and (2) to determine the quality and value of the various products which may be secured.

(*c*) *Extraction methods.*—In the distillation of resinous woods one of the most valuable products—rosin—is not secured. Methods have been developed for securing this product by extraction from the wood with chemicals, and these investigations deal with a study of such methods.

NAVAL STORES OR TURPENTINE AND ROSIN.

The naval-stores industry has long been established in this country. The general method of procedure is to tap the resinous longleaf pine trees and collect the gum, which is subsequently distilled and refined into the two major products—turpentine and rosin. Under existing methods of operations there is considerable loss of possible products owing to unscientific methods of tapping the trees and collecting the gum, while at the same time it is believed that other species than longleaf pine might prove of value for this purpose. The study of new species and the refinement of operations is the main purpose of the investigative work.

MISCELLANEOUS.

Work under this heading covers investigations which are not so broad in scope as the foregoing. They deal primarily with the utilization by transformation into other products of waste incident to mill operations and existing in the forests, and also include studies which do not deal primarily with the utilization of waste, but are nevertheless of value in furthering this work. Investigations at present under way deal with the production of ethyl alcohol, tannins, gas, essential oils from leaves and twigs, and the chemical composition of various woods.

STATISTICAL STUDIES.

This work deals with the collection and compilation of statistics on the amounts, prices, sources, and uses of various forest products produced annually and with studies to show where and how the waste

occurs and how it may be reduced. The work is of importance (1) to the Forest Service in so far as it assists in determining the lines of work which require investigations, and (2) to the Forest Service and users of wood at large in furnishing information regarding the consumption and utilization of various woods and wooden products in different sections of the country.

The work falls into the following divisions:

Annual Production of Forest Products.

This work deals with the collection of statistics showing the annual production of the major forest products and is of importance in giving a reliable yearly record of the extent and changes in the demand upon the forests for each kind of wood by States.

Uses of Woods and the Manufacture of Wooden Products.

The purpose of these investigations is to show the annual consumption of wood by the wood-using industries and to determine the conditions governing its use and the processes of manufacture. The part each species plays in wood economics is thus traced from the sawmill to the finished product. The information secured is of special value to the Government and other owners of timber, since it points out the best markets for each kind of wood. It is also of value to the manufacturer in enabling him to determine where he can best buy the material which he requires.

Lumber Prices.

The purpose of this work is to secure periodically wholesale prices of lumber both at the mills and principal markets. The information has two main applications:

1. It provides a continuous statistical record of the prices of the various woods in all parts of the country.
2. It determines the part which freight and selling charges play in determining the wholesale price of the different grades.

Miscellaneous.

This covers minor work of a statistical nature, such as the collection of statistics on the quantity of wood preservatives annually consumed and the extent of the substitution of other materials for wood.

SILVICULTURE.

The aim of the silvicultural investigations is to secure a thorough knowledge of the silvical characteristics and requirements of all forest trees, a solid scientific basis for the silvicultural handling of existing forests, and for the establishment of new forests to secure the most economic use of the timber and other products of the forest

and a more exact knowledge of its indirect benefits. The silvicultural investigations are necessarily conducted along two distinct lines, as experimental studies and general studies.

The experimental work as now conducted at the Forest experiment stations is by far the most important. For the last few years it has been felt that only by well-ordered experiments can empirical procedure be replaced by truly scientific procedure. The experimental work is carried on chiefly at the seven Forest experiment stations of the Forest Service: the Fremont Station on the Pike National Forest near Pikes Peak in Colorado; the Wagon Wheel Gap Station on the Rio Grande National Forest, also in Colorado; the Fort Valley Station near Flagstaff, Ariz., and its substations; the Priest River Station on the Kaniksu National Forest in Idaho; the Feather River Station on the Plumas National Forest in California; the Utah Station on the Manti National Forest in Utah, and at the Arlington Farm in Washington, D. C., although a large number of experiments are conducted on various Forests and in cooperation with several States on State lands.

General studies which can not be confined to one locality, such as regional or tree studies, are necessarily made where favorable conditions exist for carrying them on.

FOREST EXPERIMENT STATIONS.

The Forest experiment stations are the outgrowth of the need for scientific information which can be secured only in a systematic manner and by intensive methods of study. The Forest experiment station idea is not a new one; it has already been developed extensively in several European countries. The value of the systematic organization of Forest research work was officially recognized in Germany in 1870, when the first Forest experiment station was established in Baden, in connection with the Polytechnikum at Carlsruhe. Half a dozen of the German States followed the example, instituting main experiment stations in connection with forest schools, and branches in various forest districts. The cost to the German Government is in the neighborhood of $30,000 annually. The work done is intensely scientific, and the policy of forest experiment stations is steadily growing in favor.

In India, where the work of research has been neglected for a long time, the need for scientific investigation has now been recognized by the Government, and an Imperial Forest Research Institute and College has been created at Dehra Dun, with a faculty chosen from the Imperial Forest Service.

In the United States considerable research work has been done in connection with forest problems. The beginning of real investigative work in silviculture, however, must date from the establishment

REAR VIEW OF FORT VALLEY EXPERIMENT STATION GROUNDS, WITH SAN FRANCISCO MOUNTAINS IN THE DISTANCE. TO THE RIGHT, RESIDENCE OF OFFICER IN CHARGE; TO THE LEFT, ASSISTANTS' QUARTERS.

HEADQUARTERS OF FREMONT EXPERIMENT STATION, PIKES PEAK IN THE BACKGROUND.

of the first experiment station at Flagstaff, Ariz., in the summer of 1908. Advantages of economy and greater efficiency in conducting investigative work in silviculture at an experiment station are apparent. Under the old system of conducting investigative work, assignments to an extensive area were usually necessary, to which the observer could devote but a short field season. Under the system of Forest experiment stations, specially trained men are permanently assigned to a given region with which they have an opportunity to become thoroughly familiar and therefore are capable of conducting the work with the greatest effectiveness and least expense. Each of the experiment stations is allotted an area sufficient for the proper handling of short-period experiments, for experiments requiring a number of years, and for the maintenance of large permanent sample areas which serve as models typical of the silvicultural region. Such areas furnish the most valuable, instructive, and convincing object lessons for the public in general, for professional foresters, lumbermen, and owners of forest land, and especially for the technical and administrative officers of the National Forests.

The organization of the Forest experiment stations made possible the use of uniform methods in dealing with forest problems. General problems are treated at the different stations simultaneously; local problems in the region to which their results apply. All of the modifying factors which enter into the results of experiments are measured by observations covering many conditions and years and are thus determined once for all with the greatest economy and the least duplication of work.

The stations are distributed in such a way that one station is located in each of the silvicultural regions of the West. A single Forest, representing as much as possible the conditions typical of the region, is selected and a portion of this area set aside for the purposes of the experiment station.

Fort Valley Experiment Station.

This is the oldest station, having been established in the summer of 1908. It is located on the Coconino National Forest within 8 miles of Flagstaff, and is typical of the western yellow-pine forests of the Southwest.

Fremont Experiment Station.

This station was stablished in 1909. It was named in honor of Gen. John C. Fremont, a famous explorer of the Pikes Peak region. It is located on the front range of the Rocky Mountains, 75 miles south of Denver, 10 miles west of Colorado Springs, and 2 miles from Manitou, which is at the base of the mountains. The situation may be said to be on the slope of Pikes Peak, although the station is nearly 4 miles from the Peak and 1 mile lower than its summit. At ap-

proximately 8,850 feet elevation, the Fremont Station is almost at the middle of the forest range, timber line on the Peak being at 11,500 feet, and the lower limit of forest growth at about 6,500. Either extreme of tree growth is within 4 miles of the station. The Pike National Forest is an especially desirable site for a Forest experiment station on account of the wide range of altitude which it covers and the versatility of physical conditions within its limits. The forest types surrounding the station are those of western yellow pine, Douglas fir, and Engelmann spruce.

Wagon Wheel Gap Experiment Station.

This station was established in 1910. While it is almost in the same region as the Fremont Experiment Station, the purpose for which it was organized is entirely distinct, namely, the study of the effect of forest cover upon streamflow. It is located on the Rio Grande National Forest near Wagon Wheel Gap, and the watershed studies are carried on in cooperation with the United States Weather Bureau.

Priest River Experiment Station.

This station was organized in the fall of 1911. It is located on the Kaniksu National Forest about 14 miles from the town of Priest River. It is typical of the limited silvicultural region composed of western white pine and western larch.

Feather River Experiment Station.

This station was organized in the fall of 1912. It is located on the Plumas National Forest on the west side of the Sierras. It is within a region typical of the western slope of the Sierras where the most important species are western yellow pine, sugar pine, and incense cedar, which occur in mixture with each other and with other species such as Douglas fir and white fir.

Utah Experiment Station.

This station was organized in the fall of 1912 on the Manti National Forest, chiefly for the purpose of carrying on intensive grazing studies, especially studies of the effect of grass cover and grazing upon floods, erosion, and purity of the water supply. Since this station is located in the Wasatch range of mountains in the midst of vast areas of aspen, opportunity is afforded also for carrying on silvicultural investigations in the management of aspen stands and their replacement by conifers.

Arlington Farm, Washington, D. C.

The work at the Arlington farm is limited to seed tests in the greenhouses of the Bureau of Plant Industry and to basket-willow studies, propagation of different varieties of willows, and raising small quan-

tities of basket-willow rods of the recognized commercial species. It is not, therefore, a forest experiment station in the sense all other stations are.

The experiment stations in the different districts do not attempt to duplicate the work of each other, but each aims to concentrate on problems most typical and most urgent in the district in which it is located. Examples of this are as follows:

District 3 (including Arizona and New Mexico) has a problem of the first importance in the study of the western yellow-pine forest, its management and reproduction. The investigations in this district are therefore chiefly directed to the solution of such problems. All other districts have western yellow pine which enters more or less into the management of their Forests, but to a less extent than in District 3.

In District 2 (Colorado and Wyoming) lodgepole pine, Douglas fir, and Engelmann spruce form the bulk of the Forests. Their management and reforestation is therefore the main field for investigation.

In District 1 (Montana and northern Idaho) the western white pine and larch types, and to a considerable extent, also, lodgepole pine, attract especially the attention of the investigator. As far as the problems in the lodgepole-pine type are concerned, however, the investigations are divided, as far as possible, between Districts 1 and 2. Thus the investigations in District 1 are chiefly of growth, volume, and yield; in District 2, chiefly of seed collection, seed extraction, and reforestation.

In District 6 (Oregon, Washington, and Alaska) the experiments in the Douglas-fir type are emphasized, while in District 5 (California) the mixed forest of sugar pine, yellow pine, and incense cedar as well as eucalyptus problems are brought to the front.

The silvicultural investigations carried on by the Forest Service are conveniently classed under the following headings:

Forestation:
- General studies.
- Seed, production, fertility, methods of extraction, etc.
- Nursery practice.
- Species, methods, and seasons for artificial forestation.
- Sites—limits upon the growth of each species fixed by site conditions.
- Introduction of exotics.
- Species.

Forest influences upon climate, stream flow, erosion, etc.

Management:
- General systems and their technical basis.
- Methods of cutting.
- Brush disposal.
- Natural reproduction.
- Thinnings.
- Valuation—immature growth, merchantable timber, soil for forest production.

Mensuration.

Protection from—
- Fire.
- Grazing.
- Diseases.
- Insects.
- Animals.
- Snow.

Regional studies of types and forest conditions.
Silvical studies :
- Distribution of forest trees and types.
- Forest types—description, basis of tree associations, etc.
- Special studies.

Tree studies: Growth, yield, silvical characteristics, methods of management, etc.
Utilization studies.

FORESTATION.

The studies and experiments in forestation cover the entire field of establishing a forest by artificial means—from the collection of the seed to the final sowing of seed or planting of trees in the field. They include investigations in regard to the collection and testing of seed; factors influencing the amount and quality of seed produced, such as site, age, and condition of the tree; periodicity of seed years; effect of the source of seed, such as the locality in which the seed was produced and the condition of the mother tree, upon the size and hardiness of the seedlings. They cover experiments in the nursery as to the time of sowing, depth of covering, necessity for shade, protection from birds and rodents, age at transplanting, methods of transplanting, use of fertilizers, etc., for the various species, also experiments in seed sowing and planting of nursery and forest-grown stock to determine the comparative values of each for the various species and sites, as well as the best seasons, the best age of stock, methods of sowing and planting, the possibility of extending the range of native species, or of introducing exotics.

SEED INVESTIGATIONS.

The extensive seed collecting and seed extracting operations now carried on by the Forest Service called forth an important line of experiments with seed. This included methods of collecting, cleaning, extracting, testing, and storing of seed. The technique of handling large quantities of cones and of handling the seed receive special attention, since it is felt that this work, involving the expenditure of thousands of dollars, must, by all means, be on a scientific basis.

From the tree to the final storage room seed under artificial treatment is liable to a great many injuries in careless hands. The problems have not been thoroughly worked out by commercial seed dealers because the demand for forest tree seed has been small. Even the procedure worked out by European foresters can not be closely followed in handling our native species, such as lodgepole pine or western

FIG. 1.—HEADQUARTERS OF THE WAGON WHEEL GAP EXPERIMENT STATION.

FIG. 2.—INTERIOR VIEW OF GREENHOUSE AT FREMONT EXPERIMENT STATION, WHERE SEED TESTS ARE MADE FOR THE DISTRICT.

larch, which have peculiar cones. No doubt much difference exists in the resistance to heat, moisture, and mechanical injury of our various native species.

The problems which are aimed to be solved by these experiments are: How can cones be handled to yield the largest quantity of seed of the best quality, without impairing the germinative power under processes which are not natural but which must be resorted to for the sake of economy; how can the seed be best stored so as to retain the greatest vigor and value in producing immediate results from sowing; how to determine in the shortest time possible, and yet accurately, the fertility of the germinative vigor of the seed as a guide for sowing in the nurseries and in the field, and how the source of seed affects the vitality and future growth of the seedlings.

The source of seed has a great bearing upon reforestation work. In the practical work of planting, it frequently becomes necessary to choose between two supplies of seed available for the work, both possibly from distinct sources. To what extent the source, as well as the germinative value of the seed, may influence the success of the operation and to what extent stock from distinct points will prove adaptable to local conditions are always doubtful questions.

Some of the problems encountered are:

1. Is it advisable to use on one Forest seed collected on another Forest, which may be somewhat different as regards latitude, precipitation or character of soil, or even seed collected in a situation on the same Forest, differing radically in any of these respects? The extent to which the source of seed may have a bearing on the success of direct seeding work determines the procedure to be followed in collecting seed, in centralizing seed-extracting operations, etc.

2. Do trees which are especially heavy seed bearers necessarily produce the most thrifty and vigorous seedlings? If so, seed collecting should undoubtedly be restricted to such trees as much as possible.

3. Are certain defects of parent trees, which may, in some instances, make them prolific seed bearers, especially attractive to the collector, likely to be transmitted, as weaknesses, to their offspring, and are defects in the technical quality of the wood hereditary or purely the result of the conditions of growth? There is much evidence leading to the former supposition. If this is well grounded, every effort should be made to improve the quality of our timber while regenerating the immense areas of burns and cut-over lands.

4. Are the most rapid-growing climatic varieties adaptable to change of environment; and, if so, will they prove more valuable in any locality than the native form, or will they revert immediately to the same form and rate of growth?

5. In the introduction of species to a new region, such, for instance, as the Nebraska sandhills, where all forest trees may be considered as exotics, many unexpected natural enemies make their appearance. Probably the most important factor in success or failure, however, is climate. Despite all efforts to care for seedlings in the nursery, to protect them from disease, excessive light, and drought, and despite the efforts to make the conditions at the time of planting as favorable as possible, results so far obtained indicate that in a given situation only a certain proportion of the orginal number of seedlings of any species will survive. Failure to adapt to new conditions is the only possible explanation. Can the quality of adaptability, or original hardiness, be traced to the parent trees?

These problems are only different phases of one problem—when and how shall the seed for reforestation work be selected?

A number of experiments to answer these questions are now carried on at the different experiment stations. In order to yield conclusive results, however, these experiments will have to be carried on for several years.

NURSERY PRACTICE.

Experiments in nursery practice are confined to raising stock in the nursery. There are many problems in the handling of a forest-tree nursery in a given region which must be determined for that particular nursery. To accept the findings of an investigator who has worked with entirely different conditions of soil, climate, and tree species may be worse for the nurseryman than to be ignorant of any such investigations. For instance, nursery practices which have proved very successful in the New York State nurseries have been almost disastrous when attempted under the absolutely different conditions of the Halsey nursery, Nebraska. There are practices which would be bad under any conditions, others which with discretion might well be applied anywhere, but for the most part each nurseryman must work out his own problems.

SPECIES, METHODS, AND SEASONS—SITES.

Experiments with species, methods, and seasons, as well as with sites, are designed to determine what measure of success may be expected from different species and methods for planting or sowing on various sites. With respect to the latter point, the problem is mainly one of determining where the efforts may be best applied in the hope of encouraging the reforestation work on favorable sites, and it will usually follow, too, that the site which is most favorable for sowing and planting will produce the best timber in the shortest time. On the other hand, situations most in need of a protective forest are usually the most difficult to stock.

The methods of procedure in sowing and planting must be thoroughly worked out on a small scale in order to execute larger operations, which are much needed, most economically. The importance of this line of work can not be overestimated, nor should the value of small, carefully studied experiments be deprecated. Viewed on the basis of present plans for reforestation work, and the experience gained at experiment stations during the last few years, a thousand dollars expended in experimental work at two or three points would furnish a knowledge of methods and seasons for sowing a given species, while in a single year $10,000 might be expended without results if the work happened to be done at the wrong time or in the wrong way. The value of any method of sowing or planting must be judged entirely by the results which it produces, or, in short, the number of trees established in a new site, for each dollar expended.

The numerous problems encountered in the reforestation work, the solution of which is being attempted, may be grouped as follows:

1. Effect of situation (slope, aspect, etc.) on success of sowing and planting.
2. Effect of herbaceous, shrubby, or arborescent cover on the success of sowing or planting.
3. Effect of grazing on the work of reforestation.
4. The best season for sowing and planting.
5. The best methods of sowing and planting, or comparison of both processes, including the preparation of ground.
6. The best kind of stock for planting (in a given species).
7. The destruction of rodents, and other means to insure the success of sowings.

The best methods of reforestation and the most favorable season for sowing seed and planting nursery stock are being tested with all important trees upon the National Forests.

Studies in Range Extension and Introduction of Exotics.

Within the National Forests, as well as outside of them, in the mountainous regions, the several forest types are found in distinct altitudinal zones.

The chief differences between successive zones lie in the amount of precipitation which they receive and, less important, in a decreasing mean temperature toward the higher altitudes. To what extent the amount of moisture present in the soil and the temperature absolutely limit the altitudinal range of a species and to what extent this limitation of range of any species is due to the more successful competition of another species is still a matter of speculation. It is believed that any species is capable of adapting itself to less moisture on the one hand and lower temperature on the other than are found in its native habitat. Such being the case, it is possible that yellow pine and

Douglas fir, for instance, by far the most valuable of the four principal species concerned in the Rocky Mountains, can be made to grow in place of the less valuable piñon on the one hand and the less valuable Engelmann spruce on the other. It goes without saying that this is a problem in reforestation to be considered where there is to be no competition between the natural species of the type and the species whose range is extended into that type. In other words, can we not create temporary types in reforestation more valuable than the natural types?

To answer this question, two experiments have been inaugurated at the Fremont Station with the extension of Douglas fir by artificial sowing and planting to higher altitudes and with the extension of yellow pine to lower altitudes. These experiments, if serving no other useful purpose, will furnish more definite information than is yet available regarding the climatic limitations of successful reforestation.

What is true of altitudinal range is also true of geographic range. There are many species which occur in some National Forests and are absent in others, although the climatic and other physical conditions may be nearly the same. Thus, lodgepole pine is absent from the southeastern portion of the Rocky Mountains, yet there are many localities where it could apparently grow well.

Experiments were instituted in several of the National Forests, and especially in the Fremont Experiment Station, for the purpose of determining the possibility of introducing, by means of sowing and planting, such species as eastern white pine (*Pinus strobus*), western white pine (*Pinus monticola*), lodgepole pine, Norway pine, and several others which do not occur there naturally, but whose climatic requirements do not differ essentially from the other species growing in those localities.

While the Forest Service is not directly concerned with the introduction of any foreign species into this country, and believes that our own forest flora is so rich in species that it is possible to find trees practically for any situation and soil, yet there are a few species abroad the advantage of which is so evident that the Forest Service carried on several experiments for the purpose of determining their suitability in this country. Among the species are cork oak, maritime pine, Austrian pine, European larch, Norway spruce, Scotch pine, eucalypts, and acacias (wattles).

FOREST INFLUENCES.

Experiments in forest influences aim to determine the relation of forests to climate and stream flow and also to obtain data necessary for a proper understanding of all other silvicultural experiments in which the climatic factor enters into the results. The essential fea-

FIG. 1.—PRIEST RIVER EXPERIMENT STATION, IDAHO, LABORATORY AND OFFICE BUILDING.

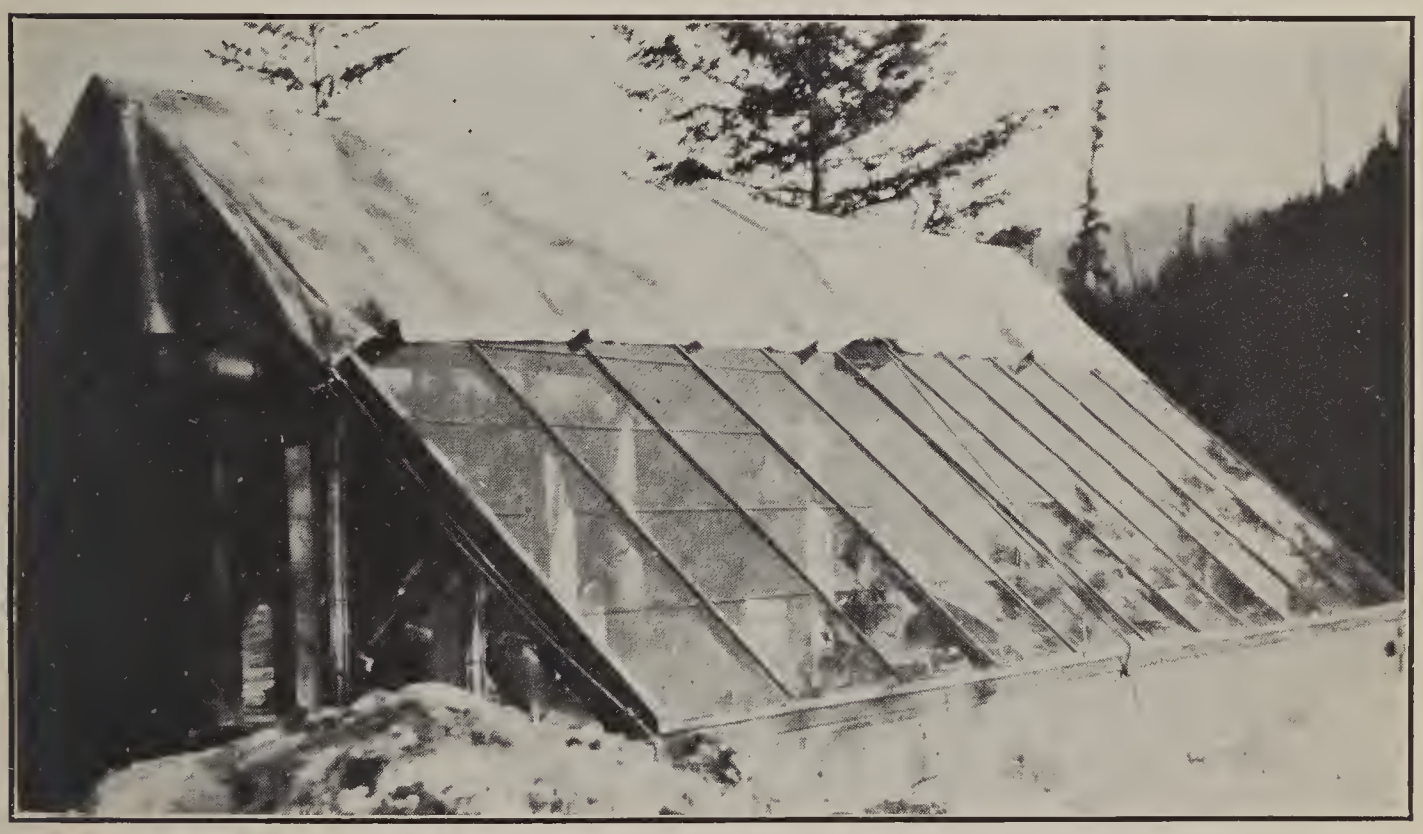

FIG. 2.—PRIEST RIVER EXPERIMENT STATION GREENHOUSE.

Control Meteorological Station on Benton Flat, Priest River Experiment Station. In background an even-aged stand of 50-year-old western larch. Situation representative of the larch type of northwestern Montana and Idaho.

tures of these experiments are meteorological observations arranged in such a way as to bring out the relation between vegetation, climate, and stream flow. These observations are carried on in cooperation with the United States Weather Bureau. The cooperative plan agreed to by the Weather Bureau provides that it shall furnish the instruments for observations of air, temperature, humidity, precipitation, and wind velocity. In most cases three sets of instruments are installed at the same experiment station, either in different forest types or in the forest, on the edge of the forest, and in the open.

One of the most important forest influences is considered to be its effect upon stream flow.

There is still some skepticism as to the great value of the forest cover in retaining the water of precipitation and preventing its rapid run-off. The results of European investigation of this and other matters concerned with the indirect influence of the forest must not be taken as final, or even as having very great bearing on the question as presented in this country. The fact that Europeans have found very little difference between the climate inside and that outside the forest, that they have noted no great change in the flow and quality of their streams, etc., is easily accounted for on the ground that their observations have covered no great range of climatic conditions, and that they have practically all been made since the time when the forest area assumed its normal position in the balance. No such extremes of climate as this country possesses, or such a change in the forest cover as has been witnessed here in the past century, are to be imagined for any country in Europe, and hardly for the whole continent. The study of the effect of forest cover upon stream flow is studied at the Wagon Wheel Gap Station, which has been established entirely for this purpose. The object of the stream-flow experiment as it is conducted on the Rio Grande National Forest is to determine by means of the most highly accurate measurements the effect of forest cover upon the high and low water stages of mountain streams, the total run-off from mountain watersheds as compared with the annual precipitation, and the erosion of the surface of such watersheds. The measurements of factors concerned are so made as to furnish in a general way an estimate of the relative amounts of run-off and evaporated water of each watershed. Since, as has been shown by geological examination, there is very small possibility of an escape of the water of precipitation, by percolation, other than through the main channels of the streams involved, there is no third element to be measured.

In the present case the comparison of the forested and nonforested mountain watershed is obtained in a manner which can not fail to give convincing results. Measurements of the streams in two watersheds, both moderately well covered with forest, will be con-

ducted for a number of years with the measurements of all the factors which may affect the character of the flow of each stream. By this process a certain relation will be established between the two streams for different sets of conditions of different characters. For instance, it will be found that a given amount of precipitation produces in one watershed a flood of a given height and in the other watershed a flood of slightly different height, but both influenced by forest covers of practically the same character. Or, again, a given amount of snow melting under a given maximum and mean daily temperature of air and soil produces a given flow in each stream. When this comparison has been carried long enough to furnish a number of relations between the two watersheds, one watershed will be denuded and the forest cover upon the other will be retained. There will be, therefore, upon the forested watershed the same conditions affecting the flow of the stream in that watershed as during the earlier part of the experiment, while upon the denuded watershed the conditions will have been changed only so far as forest cover is concerned, and any changes in the relative behavior of the two streams as before and after the denudation must therefore be accredited to the change in forest-cover conditions. To cite a hypothetical case: With the forest cover on both watersheds a rainfall of 1 inch in 1 hour produces a flow in the watershed A of 1 foot of water over the weir, the crest of the flow occurring 2 hours after the beginning of the precipitation as recorded by the time record at the head of the watershed and automatic stage register at the measuring point of the stream. In watershed B the same precipitation produces a flow of 15 inches over the weir, occurring $1\frac{3}{4}$ hours after the beginning of the storm. The two streams during the progress of this flow deposit an equal amount of silt in the settling basins as measured by actual weight, and samples of the water passing out of the basins are shown to be carrying the same amount of finer silt which does not settle.

After the denudation of watershed B, a similar storm produces in watershed A a similar flow as regards volume and time, while in watershed B it produces a flow of 20 inches, occurring $1\frac{1}{2}$ hours after the beginning of precipitation, and it is found that a much larger amount of silt has been deposited in the settling basin.

It must be admitted that such comparative records as these, whether or not they prove the contention as to the value of forest cover in retarding run-off and preventing erosion of the slopes of watersheds, must carry conviction which can not fail to be of assistance toward a proper understanding of the value of mountain forests.

MANAGEMENT STUDIES.

The purpose of these studies is to determine the best methods of cutting in the different forest types in order to secure natural reproduction in the shortest possible time. The most economical and best method of reforestation is, of course, by natural seeding from the trees left on the cut-over land or from trees adjoining the cutting. These studies include also experiments in assisting natural reproduction by various methods of brush disposal, destruction of unfavorable ground cover, soil preparation, and other means. By the study of cut-over areas in which there is already partial reproduction much time may be saved in obtaining results. The old cuttings, however, did not follow any distinct silvicultural systems, and few, if any, followed the systems which we may hope to adopt in the future. For the most thorough studies, therefore, it is necessary to select small areas of timber sales and follow out an ideal system of cutting, sometimes at slight additional expense, since it is frequently necessary to overreach the terms of the contract under which the main cutting is being done. While a fair beginning has been made in experiments of this character, there are few results available as yet, since it will take several years before the effect of one or another method of cutting will show itself upon the success or failure of natural reproduction.

Studies in management include further experiments in thinnings to determine the effect of improvement cuttings on the volume and quality increment of the remaining trees for various exposures, types, and species with special reference to the relation of the cost of such thinnings to the value increment. While thinnings as a distinct cultural operation will be hardly applicable yet for many years in most of our forests, there are types where the removal of certain classes of trees is practicable at present and is of benefit to the remaining stand. Such stands are found in the lodgepole pine, Douglas fir, and in some instances also in the yellow pine types. Thinning experiments are now conducted on a number of Forests, especially in Districts 1 and 2.

Methods of determining the value of land for agricultural or forest purposes, and of ascertaining the damage caused by fire to immature or mature stands, form also a part of management studies. While there are definite mathematical formulas for calculating the productive capacity of the soil and the value of immature timber, the application of the formulas depends on many factors, such as the rotation adopted for the different species, stumpage prices, cost of natural or artificial reforestation. These factors must be carefully studied before we can be certain that the formulas used answer the present economic conditions of forestry in this country.

MENSURATION STUDIES.

The proper handling of timber sales as well as the management of the forests must necessarily be based on reliable data as to the growth, volume, and yield of the different species and types of forests. They are also essential for determining the damages caused by fires, trespass, etc. The purpose of growth studies is first of all to collect such data, and from them to establish certain laws of tree growth. In addition, studies in mensuration include comparison of different methods of gathering data; for instance, whether the accretion borer or stump analysis should be used for determining the rate of growth, tape or calipers for standing trees on sample plots, strip surveys, or ocular estimates for determining yield in reconnaissance work. The work of collecting growth and yield data is carried on largely in connection with the reconnaissance work in the districts and is confined to timber-sale areas which afford the best opportunity for measuring large numbers of trees, and to permanent sample plots which present the best means for measuring the growth of standing timber. Such data are also collected in connection with tree studies.

To the growth and yield studies belong also the establishment of permanent sample plots. The purpose of the sample plots is to have in forests typical for a given region and species definitely and distinctly marked areas on which all the trees are carefully measured and within which certain silvicultural operations, such as thinnings, improvement cuttings, etc., are made. These areas are measured at definite intervals for each experiment, and the results of thinning, opening up of the forest, or removal of the litter which find their expression in the growth of the trees are studied. These areas at the same time furnish yield data, that is, the amount of timber that can be secured from forest land at certain ages of the stand. Most of the sample plots are now established on the National Forests in connection with other studies. In the East sample plots were established on State and private land, and many of them which were established five years ago were recently remeasured. While these sample plots are extremely valuable in themselves, they are also used in connection with other studies, such as tree studies or the best methods of handling timberlands or farmers' woodlots. The sample-plot method is the most reliable one for studying forest problems, and furnishes the basis for American forest management.

PROTECTION STUDIES.

These studies aim to ascertain the extent of the effect caused by fire, grazing, diseases, insects, animals, and climatic agencies, such as snow, hail, and wind, upon standing timber and natural reproduction. The studies of the effect of grazing form a part of the graz-

ing studies conducted by the Branch of Grazing and are taken up more fully under the head of Grazing. The object of these investigations is to secure definite data in regard to actual amount of damage done to natural reproduction by grazing, and of devising a system of range control whereby the damage may be minimized without the total exclusion of stock. The relation of grazing to fire protection, the use of goats for destroying chaparral, and thus preparing for reforestation are among the problems taken up under this head.

While the investigations of the diseases of trees are under the direction of the district pathologist of the Bureau of Plant Industry, much information is being collected by the Forest Service as to the effect and extent of various tree diseases, such as rot, mistletoe infestation, witches' brooms, leaf and seedling diseases. Similarly, while the investigations of insect infestations are in charge of the Bureau of Entomology, studies of the actual insect control, the location and extent of infested areas are carried on by forest officers. Specimens of injurious insects, together with specimens of their work, are collected and forwarded for identification to the Bureau of Entomology.

Habits and detrimental or beneficial effects of wild animals upon forest growth, damage by rodents and birds in destroying seed or seedlings, and methods of combating such animals are a part of the studies conducted under Forest Protection. These studies are carried on in cooperation with the Biological Survey, which decides upon the most effective methods of combating the animals.

REGIONAL STUDIES.

Regional studies aim to secure authentic information concerning the forest resources of State or forest regions. They deal with problems peculiar to the region or State and are therefore of direct benefit to the timber and woodlot owners of that State or region. Most of the studies are carried on in cooperation with the States and are published by the States. The regional studies provide information applicable to the timberland or woodlots within that region. This enables the Forest Service, in advising the individual timber or woodlot owner, to do away to a large extent with the necessity of examining each individual woodlot. Aside from the practical value of such regional studies they contribute to a more exact and fuller knowledge of the forest resources of this country and their distribution.

SILVICAL STUDIES.

The proper aim of silvical studies is to establish a definite relation between the forest region, forest types, and forest trees in general, and the climatic and physical factors affecting their distribution and growth. Silvical studies are, therefore, largely forest ecological

studies. The silvical studies proper are largely concerned with the studies of types, their origin, characteristics, permanence, and their development from the seedling stage to maturity. They seek to correlate the vegetative phenomena of tree growth, such as leafing, flowering, seed ripening and dissemination, and leaf falling, with climatic factors. They attempt to determine soil, moisture, and light requirements of the different species and the methods of determining these requirements of forest trees. These studies are basic and form the foundation upon which the practical application of the silvicultural methods must rest.

TREE STUDIES.

The purpose of tree studies is to secure information concerning the important forest trees of this country as a basis for their proper management. The results of such studies appear as monographs dealing with the range of each tree, its silvical characteristics, yield, and management.

The studies of individual trees in the forest embrace those points usually included in a silvical study, habitat, silvical characteristics and requirements, form, volume, growth, seeding capacity, enemies and diseases, phenology, etc. The requirements of trees are studied not only by general observations but by actual measurements of the physical factors in which they are growing, and the results are expressed as far as possible in absolute figures. Thus, in studying the light or moisture requirements of a species the actual light intensity or water contents of the soil in which it grows is measured.

UTILIZATION STUDIES.

While problems in the utilization of timber are best handled by the Madison laboratory, yet the field studies in silviculture also present many opportunities for experimentation along this line. The vast areas of fire-killed timber bring up the question as to the length of time during which the fire-killed timber may still remain serviceable and therefore merchantable. The rapidity and the causes of deterioration of fire-killed timber is of vital interest, and studies to determine these facts are now carried on in a number of National Forests, especially within the area visited by the disastrous fires of 1910.

Since it is frequently necessary to leave mature or overmature trees for seed production, it is important to know how long such trees will continue to bear seed and how soon they will become unmerchantable. To this end records are established at several of the experiment stations on a number of trees in various stages of decadence. The records include the number, location, diameter breast high, crown and bole description, and effects for each individual tree.

Aside from the utilization studies there is a distinct field for silvical investigation in connection with the studies of the technical qualities of wood. There should be established a definite relationship between the technical qualities of timber and conditions of their growth—various altitudes, soils, and slopes. This relationship would enable such handling of the growing forest as to secure the most desirable qualities by means of silvical operations.

THE PROGRAM OF INVESTIGATIVE WORK FOR 1912.

In accordance with the investigative organization adopted this year a program of investigative work for 1912, submitted in the prescribed manner, has been approved by the Forester. This program includes 353 investigative projects.

DEFINITION OF A PROJECT.

In preparing the Service program each investigation having a single object but involving one or several similar operations was considered a distinct project. The object, however, must not be too minute, but must aid at the solution of some problem of broad importance. What is considered as a project can best be shown by the following examples: In reforestation work all methods of sowing or planting the same species at different times of the year in a single district were included under one project. Thus yellow-pine sowing or planting by different methods and at different seasons in District 2 constitutes a single project. In products work all tests of mechanical properties of wood, based upon small specimens from commercial species in the United States, are classed as one project, not the tests on each individual species.

By thus combining as one project a number of operations having the same object, an opportunity is afforded to correlate the results and arrive at more definite conclusions than if each operation is considered separately. The final determination of what constitutes a problem of sufficient importance to class as a project must rest with the administrative officers directing the work.

The program of work, as approved, is given below:

DENDROLOGY.

A.—DESCRIPTION AND DISTRIBUTION OF NORTH AMERICAN TREES AND SHRUBS.

Project.	Object.
Forest trees of the United States: Rocky Mountain region, Northeastern region.	To bring together in a comprehensive manner all the available information on botanical and silvical characteristics of forest trees by regions.
Shrubs of the United States.	To bring together all available information on the botanical characters of shrubs for the purpose of identification.
Forest distribution studies...	To determine the geographic distribution of North American trees and shrubs.
Study of the forest flora. (Herbarium.)	To collect specimens of different species of forest trees and shrubs for use in dendrological and silvical studies, and in the identification of specimens which are sent in, and also for supplying the Washington and district herbaria with a full set of specimens.

B.—IDENTIFICATION OF NORTH AMERICAN FOREST TREES.

Wood structure.

Distinguishing characteristics of the wood of North American trees: North American walnuts, sycamores, elms, pines, hickories, jack pine, red pine.	To determine the structural and other distinguishing characters of different species and groups of woods for the purpose of identifying them.
Hand collections of 75 species of commercially important North American woods for distribution to educational institutions and to Forest districts.	To furnish collections to schools and districts.

General.

Identification of seedlings and mature catalpa trees by means of the wood structure and external characters.	To determine reliable means for identification of the wild and cultivated species of catalpa.
The distinguishing characters of turpentined pine woods of the South.	The identifications of wood from trees that have been turpentined.

C.—IDENTIFICATION OF EXOTIC FOREST TREES.

Wood structure.

Project.	Object.
Distinguishing characteristics of Circassian walnut wood.	To determine the structural characters which distinguish this wood from common substitutes.
Distinguishing characteristics of tropical and subtropical woods:	
True mahogany.....	To furnish information on the distinguishing characters of the different grades of true mahogany wood.
Panama woods.....	To furnish information on the distinguishing characters of commercially important woods of the Panama zone.
Greenheart.....	To furnish information in regard to the distinguishing characters of greenheart wood.

D.—SPECIAL STUDIES.

Pith flecks in North American woods.	To determine the cause of pith flecks in North American woods and their value as distinguishing characters.

GRAZING.

A.—ARTIFICIAL RESEEDING.

Restoration of overgrazed areas and improving the quality of forage by artificial reseeding with cultivated plants.	To determine under what conditions seeding can be successfully undertaken, methods of seeding, time of seeding, amount of seed, cultural treatment, and methods of handling the lands during the restocking period.
Introduction of forage plants in the Southwest.	To determine the possibility of improving range conditions in District 3.
Relation of soil acidity to artificial reseeding.	To determine (1) cultivated species best adapted to acid soils; and (2) how to recognize strongly acid soils by character of native vegetation.
Cultivation of indigenous forage plants with a view to their use for artificial reseeding of the range.	To carefully select a few promising native forage plants, collect seed in native habitat, put it under cultivation at Forest experiment stations, and to determine the possibility of securing seed for distribution at a cost not prohibitive.

B.—NATURAL RESEEDING.

Restoration of overgrazed areas by the natural reseeding of native forage plants.	To determine (1) the possibilities of naturally reseeding depleted lands that still have part of the stand of native vegetation; and (2) to devise a system of grazing which will accomplish this result if possible.
Rotation grazing.....	To study the practical application of a rotation system of grazing developed as a result of the preceding study to determine more fully (1) the advantages of this system, over existing systems, to the range and to the stock; and (2) to what extent it can be applied in the practical management of Forest ranges.
Range improvement by natural reseeding.	To determine the possibility of increasing carrying capacity of much depleted range on Hayden Forest without total restriction of grazing.

C.—DISTRIBUTION AND ECONOMIC IMPORTANCE OF FORAGE PLANTS.

Project.	Object.
Life history, forage value, and ecological requirements of important forage in the mountains of northeastern Oregon.	To determine the entire life cycle of important forage plants in this locality as a basis for judicious management of the grazing of lands supporting these plants.
Distribution, life history, and economic importance of forage plants.	To bring together valuable information on this line collected in connection with range reconnaissance by special grazing men.
Distribution, natural habits, and economic importance of forage plants.	The collection and identification of forage plants on important grazing Forests, accompanied by notes on distribution, growth requirements, and forage value.

D.—FOREST PROTECTION (GRAZING).

[Listed under "Silviculture—Protection."]

E.—METHODS OF HANDLING STOCK.

Small coyote-proof inclosure in connection with range lambing allotments.	To determine the possibility of (1) decreasing damage to range during lambing period; (2) increasing percentage of lambs saved; (3) decreasing cost and difficulty of handling.
Improved methods of handling sheep on Forest range.	To study the practical application of results from Oregon pasture experiment to determine (1) possibility of keeping sheep away from an established camp; (2) advantages of such a system to the range and the sheep as compared with existing methods; and (3) determining how many sheep should be run in a band.
Using range without water for sheep grazing.	To ascertain (1) kind of forage; (2) climatic conditions; and (3) method of handling sheep which are essential if range without watering places is used for sheep grazing.
Carrying capacity of range...	To secure actual figures on the number of acres of range of a given type necessary to support a sheep.

F.—DEVELOPMENT OF STOCK-WATERING PLACES.

Methods of developing stock-watering places.	To bring together available data on subject to determine (1) under what conditions to develop water; (2) most efficient methods of development; (3) capacity of watering place necessary per head of stock.

G.—POISONOUS-PLANT INVESTIGATIONS (COOPERATIVE).[1]

Loco-weed disease.....	To determine (1) poisonous species; (2) under what conditions poisoning occurs; (3) antidote; (4) management of stock on poison areas; and (5) eradication of plants.
Larkspurs as poisonous plants.	Same as above.
Rubber weed as a poisonous plant.	Same as above.
Lupines, death camas, and miscellaneous poisonous plants.	Same as above.

[1] Forest Service cooperates by selecting field stations, aiding in equipping stations, collecting information as to extent of losses and locality of loss, and to the extent of $2,000 for salary and expenses. Has nothing to do with collection of scientific experimental facts.

H.—SPECIAL STUDIES.

Project.	Object.
Reclamation of mountain meadows depleted by erosion.	To determine possibility of constructing small dams in erosion gullies, checking velocity of water, and silting up gullies.
Effect of grazing upon erosion, streamflow, and purity of water supply.	To determine the effect of grazing upon erosion, streamflow, and purity of water supply.

PRODUCTS.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS.

Mechanical properties.

Project.	Object.
Tests on small specimens free from defects.	
Mechanical properties of woods grown in the United States.[1]	To establish scales by means of which it will be possible to compare directly the bending and compressive strength, shearing, stiffness, toughness, specific gravity, etc., of the commercial timbers of the United States.
The relation between static and impact loading in testing mechanical properties of wood.	To determine the relation between static and impact loading on the mechanical properties of wood.
Tests to determine the strength of wood beams under continuously applied loads.	To determine the effect of continuously applied loads upon the mechanical properties of woods.
Tests on structural timbers.	
Tests on redwood.....	To determine the mechanical properties, and to investigate the influence of different localities on strength.
Tests on green and air-dried western yellow pine.	Same as above.
Tests on western larch.....	Same as above.
Tests on the mechanical efficiency of joints and fastenings in wooden structures.	To determine the efficiency of various types of joints and fastenings used in wooden structures.
Investigation of lumber waste in building scaffolding, and the introduction of new methods.	To secure information which will assist in reduction of waste in building scaffolds and in the possible utilization of thinnings for this purpose.
Tests on manufactured articles.	
Tests of packing boxes, in cooperation with the bureau for the safe transportation of explosives and other dangerous articles.	To determine the suitability of various types of boxes for use in the transportation of explosives and other dangerous articles, and to secure data upon which specifications and improvements in design of such boxes may be based.

[1] Select species for test to correlate with Silviculture's commercial tree studies.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS—Contd.

Mechanical properties—Continued.

Project.	Object.
Tests on manufactured articles—Continued.	
Tests of poles.....	To determine the comparative strength and stiffness of various species which are not now used extensively for poles, but which are believed to be satisfactory for this purpose.
Study of wood which may be used as substitute for dogwood and persimmon for the manufacture of shuttles.	To determine what woods are suitable substitutes for dogwood and persimmon for use as shuttles.
Effect of preservative treatments, etc., on strength.	
Effect of commercial processes of creosoting on the strength of structural timbers.	To determine the effect on the strength of southern yellow pine and Douglas fir bridge stringers of treating with creosote by the Bethell and boiling processes.
Effect of mechanical operative features of pressure wood-preserving plants on the strength of wood.	To determine the effect upon the strength of wood of the various steps and manipulations of commercial wood-preserving processes.
Relative efficiency of various wood preservatives.	To determine, in conjunction with other experiments to be conducted under this project, the effect of various preservatives on the strength of wood.

Physical properties.

Fundamental properties.	
Specific heat and heat conductivity of wood.	To determine the specific heat and heat conductivity of different woods.
Penetrability of woods to liquids and gases.	To secure information on the exact ways in which liquids and gases penetrate wood and wood substances.
Relation of the hygroscopic condition of wood to temperature and vapor pressures.	To determine the hygroscopicity of wood, or its relation to atmospheric moisture at various temperatures.
Determination of the heat of absorption of water in wood.	To secure a short method to determine the relative hygroscopicity of various woods.
Specific gravity of wood substance.	To determine the specific gravity of wood substance.
Conditioning experiments.	
Air seasoning of structural timber.	Correlate, analyze, and compile all available data on this subject.
Experiments with small single chamber experimental kiln.	To determine the best methods for controlling the humidity and temperature conditions in the kiln with different forms and species of lumber.
Experimental operation of a continuous chamber dry kiln of commercial size.	To determine the best methods for controlling the humidity and temperature conditions in a continuous chamber dry kiln of commercial size.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS—Contd.

Physical properties—Continued.

Project.	Object.
Conditioning experiments—Continued.	
Operation of single chamber dry kiln of commercial size.	To determine the best methods for controlling the humidity and temperature conditions in a single-chamber dry kiln of conmercial size.
Study of commercial processes used in kilndrying.	To secure information regarding the present commercial practice in use at various types of kiln in various sections of the country.
Analytical study of artificial methods of drying wood.	To determine the effect on wood of subjecting it to high temperatures and pressures, and to various conditions of the surrounding medium, and the investigation of the fundamental factors in the treatment and seasoning of woods.
General studies.	
Temperature changes in wood under treatment.	To determine the temperature changes which occur in wood when subjected to various conditions and temperatures of the surrounding medium.
Experiments in gluing black-gum lumber.	To determine methods of seasoning and conditioning which give best results in gluing black-gum lumber.

Structure.

Correlation of the microscopic structure of commercial woods with their properties and uses.	To determine the relation of the structure of woods to its properties and uses.

B.—WOOD PRESERVATION.

Preservatives.

General.	
Tests of the comparative efficiency of various wood preservatives.	To determine the relative efficiency of various preservatives which are in commercial use or proposed.
Efficiency of various fractions of coal-tar creosote in protecting southern yellow pine from marine borers.	To secure data on the comparative value of fractions of creosote in preventing the ravages of marine borers.
Investigations relating to problems connected with the use of treated wood-block pavements.	To secure information which will assist in solving the problems which confront the wood-block paving industry.
Physical and chemical properties.	
Classification of authentic creosotes.	To determine the composition of creosotes obtained from commercial tars in this country in order to correlate the methods of production with their composition and properties, and to develop methods by which the important differences in composition can be distinguished.

B.—WOOD PRESERVATION—Continued.

Preservatives—Continued.

Project.	Object.
Toxicity.	
Toxicity of preservatives with pure cultures in Petri dishes and jars.	To determine the relative toxicity of various preservatives which are in commercial use or proposed.
Fungicidal properties of coal-tar creosote fractions.	To secure data on the comparative fungicidal properties of the various fractions of coal-tar creosote.
Processes new or proposed.	
Boucherie experiments on the Eldorado National Forest.	To determine a cheap and efficient method for treating poles where costly preservatives can not be economically secured.
Boucherie experiments on loblolly pine.	To determine the practicability of using the Boucherie method of treatment with loblolly pine.
Effect of varying conditions during treatment.	
Experiments on mechanical operative features of pressure wood-preserving plants. (Project 119.)	To investigate the effects of the various operations on the absorption, penetration, and other features of the treatment of wood.
Suitability of species.	
Resistance to impregnation with preservatives.	
Relative resistance of commercial angiosperms to injection with creosote.	To classify the various species according to their relative resistance to creosote.
Relative resistance of commercial gymnosperms to injection with creosote.	Same as above.
Relative resistance to decay.	
Relative resistance of untreated woods to decay by pure cultures of fungi in jars.[1]	To secure data which will show the comparative durability of different species of woods grown in the United States.
Determination of the minimum and maximum moisture content of wood which permits the growth of fungi.	To secure data which will show the limits of moisture in wood which are necessary for the development of wood-destroying fungi.

[1] In conducting these experiments and in the preparation of bulletins an attempt should be made to correlate and combine the results with those secured by the experiments of the forest pathologists on the National Forests.

B.—WOOD PRESERVATION—Continued.

Cooperative field work and service tests.

Project.	Object.
Service tests.	
Inspection of treated and untreated timbers of various forms placed under actual conditions of service.	To determine under actual conditions of service the comparative efficiency of various forms and species treated with different preservatives and processes and untreated. Includes inspection of treated and untreated ties, poles, posts, mine timbers, paving blocks, etc., of various species placed for test purposes.
Durability data on untreated fence and pole lines on the National Forests.[1]	To secure data on the length of service of untreated post and pole lines constructed on the National Forests.
Service tests on treated and untreated eucalyptus crossties.	To secure data on the suitability of this species for ties.
Service tests on treated and untreated Douglas fir ties.	Same as above.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER.

Pulp and paper.

Mechanical or grinding processes.[2]	
Pulp-making qualities of various species of wood other than spruce.	To determine the value of different species for the production of ground-wood pulp.
Fundamental laws of grinding.	To determine the effect of pressure, speed, surface of stone, temperature of grinder, diameter of wood, and length of time wood is seasoned on the horsepower per ton, production per day, and quality and yield of pulp, using spruce as a species.
Effect of using different natural and artificial pulp stones on the quality and production of pulp.	To determine the effect of the Lombard (natural), Walker (artificial), and Hercules (artificial) grinding stones on the horsepower per ton, production per day, and quality and yield of pulp, using spruce as a species.
Effect on ground-wood pulp of steaming or cooking the wood.	To determine the effect of steaming and cooking the wood in different ways upon the production, horsepower, and quality and yield of pulp secured.
Chemical processes.	
Comparative pulp-making tests on various woods.	To determine the value of different species for pulp produced by the soda, sulphite, and sulphate processes, and the suitability of the pulps for various grades of paper. The following species to be tested in 1912: Redwood and its bark, red fir, lodgepole pine, weathered tamarack, jack pine,

[1] In carrying out these experiments, cooperation with the experiment station in the district should be secured.

[2] The individual experiments listed under this heading will all be conducted more or less jointly; that is some of the data secured from one experiment will be of assistance and use in the other experiments. It is important that the various projects be conducted together and at very nearly the same time.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER—Continued.

Pulp and paper—Continued.

Project.	Object.
Chemical processes—Contd.	
Fundamental cooking conditions in the soda process.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals, aspen to be used as a standard species and results to be checked with other species.
Study of the fundamental cooking conditions in the sulphite process.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals, white spruce to be used as the standard species and results to be checked with other species.
Study of the fundamental cooking conditions in the sulphate processes.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals.
Effect of mechanical treatments on the quality of chemical pulps.	To determine the effect of various mechanical treatments of chemical pulp on its quality.
Effect of preliminary treatments with steam and vacuum on the cooking of chemical pulps.	To secure data on the effect on chemical pulp of preliminary treatments prior to cooking.

Wood distillation.

Hardwoods.	
Destructive distillation of hardwoods.	To determine the yields of valuable products which can be obtained by the distillation of various species of hardwoods not used for this purpose at present. The following species to be tested in 1912: Birch, maple, and beech (tested for purposes of comparison with other species); oak, red gum, hickory, and chestnut.
Methods for increasing the yields of valuable products in the destructive distillation of hardwoods.	To determine what methods will result in the greatest yield of valuable products secured in destructive distillation of hardwoods.
Study of the refining methods for hardwood distillates.	To determine best methods for refining hardwood distillates in order to secure the greatest quantity of valuable products.
Resinous woods.	
Distillation experiments on northwestern woods in cooperation with the University of Washington.	To secure information regarding the value of northwestern woods for distillation.
Study of methods and processes used in securing rosin by extraction from the wood with chemicals.	To secure data regarding "extraction" methods for securing rosin.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER—Continued.

Naval stores.

Project.	Object.
The naval-stores industry...	General review of past and present methods, and recommendations.
Turpentine experiments.....	To determine the value for turpentining of the following species: Digger pine, western yellow pine, sugar pine, lodgepole pine, Jeffrey pine, and Douglas fir.

Miscellaneous.

Production of ethyl alcohol from wood.	To determine the best conditions for digestion of the wood, such as diameter, time, pressure, and kind and amount of acid, for the production of ethyl alcohol.
Production of tanning materials from woods and barks.	To make experiments with various species from time to time as is deemed advisable to determine their value for the production of tannin.
Investigations into the manufacture of producer gas from wood waste.	To determine the economic value of the manufacture of producer gas from wood waste.
Investigation of the production of volatile oils from leaves and needles of various conifers.	To determine the character and quantity of the volatile oils which can be secured from the leaves, needles, and cones of various conifers.
Comparison of the chemical composition of different woods.	To secure information regarding the chemical composition of different species.

D.—STATISTICAL STUDIES.

Annual production of forest products.

Collection of statistics of forest products in cooperation with the Bureau of the Census.	To show in detail the annual demand upon each kind of wood in the forests of the United States, the fluctuation in years of prosperity and depression, tendencies in wood utilization, changing use of species, and progress in methods to increase the service of wood.

Uses of woods.

Study of the uses of commercial woods.	To secure authentic information and statistics regarding the present uses of the various commercial woods in the United States.
By States.....	To make an inventory of the annual demand by the various wood-consuming industries in each State for raw material.
By industries.....	To secure authentic statistics and information regarding the uses of different woods classified by industries.
By species.....	To secure authentic statistics and information regarding the uses of different woods classified by species.

D.—STATISTICAL STUDIES—Continued.

Lumber prices.

Project.	Object.
Quarterly statistics on lumber prices f. o. b. mills.	To secure periodically wholesale prices of lumber at representative mills in different sections of the country.
Quarterly statistics on lumber prices f. o. b. markets.	To secure periodically wholesale lumber prices at representative markets in different sections of the country.

Miscellaneous.

Collection of statistics on wood preservatives consumed and kind and quantity of timber annually treated in the United States.	To secure data on the kind and quantity of wood preservatives annually consumed, and kind and quantity of material annually treated.
Service tests of eucalyptus and tan-bark oak for cooperage, cross-arms, and insulator pins.	To secure data on the suitability of eucalyptus and tan-bark oak for cooperage, cross-arms, and insulator pins.

Mill scale studies.

[See "Silviculture—Mensuration."]

SILVICULTURE.

A.—FORESTATION.

General.

Reforestation in the East....	To obtain reliable data as to the results of planting in the East with different species as a basis for recommendations to the farmers, and incidentally secure data on growth, volume, and yield of the different species.
Reforestation.....	To prepare manual of nursery work and field planting.

Seed.

Seed-storage experiments....	To determine the best method, temperature, and geographical location for the storage of seed.
Physical characteristics and vitality of forest-tree seeds.	To obtain information as to the germinability, variation in size of the same species but from different sources, and other physical and biological properties of the seeds of coniferous species.
Influence of age and condition of the tree upon seed production in western yellow pine.	To determine the effect of age and condition of seed trees upon the quality of seed produced and resulting generation.

A.—FORESTATION—Continued.

Seed—Continued.

Project.	Object.
Seed cleaning:	
Western yellow pine....	To determine the effects of moisture treatment for the removal of wings from western yellow-pine seed.
Seed extraction:	
District 1—	
Eastern white pine, Norway pine, jack pine, western larch.	To determine the best temperature and conditions for extraction of seed.
District 2—	
Lodgepole pine.....	To determine the relative value of lodgepole-pine seed extracted at various periods during the fall and winter.
Lodgepole pine.....	To determine the limitation on heat, soaking, etc., desirable in the extraction of lodgepole-pine seed. To determine also the merits of wet and dry cleaning of seed.
Lodgepole pin	To determine the possibility of opening cones of lodgepole pine in direct flame.
Seed testing:	
District 7.....	To determine the true value of seed collected in the districts.
District 1.....	To determine the germinating power of samples of seed used in the district; also for the purpose of determining the results of seed-extracting methods.
District 3.....	To determine the germinating power of all seed samples, concerning which information is desired for the next season's sowing in the district.
Comparative germination in the greenhouse and field.	To determine the comparative germination of seed tested in the greenhouse with that which occurs in actual field operations.
Seed production:	
Western white pine, lodgepole pine, Douglas fir, yellow pine, Engelmann spruce.	To develop a method for determining the amount of seed produced, and determine the periodicity of seed years of different species.
Source of seed:	
District 1.....	To test the source of seed of western yellow pine, white pine, and Douglas fir.
District 2—	
Douglas fir, yellow pine, lodgepole pine, Engelmann spruce.	To determine the relative value at a middle point of seed and stock from the middle, northern, and southern parts of the range of the species.
District 3.....	To determine the suitability of seed of western yellow pine from different sources to local conditions.

A—FORESTATION—Continued.

Nursery.

Project.	Object.
Nursery practice:	
District 1	To test different amounts of seed for seed beds, methods of sowing, and depth of covering.
District 2	To determine the final effects of different degrees of watering in the nursery on the stock when it is set out in the field; the effect of shading for different periods on the hardiness of trees when placed in the field; the relative values of manure, leaf compost, and commercial fertilizers; the best time for transplanting and the latitude in time of safety in spring transplanting operations; the most advantageous seasons for seed sowing in the nurseries; the best depth for sowing seed in seed spots and in the nursery; the effect on root development of Engelmann spruce of pruning roots at time of transplanting; the effect on root and crown development of square and oblong spacing in the transplant beds.
District 3	To determine various phases of nursery practice, such as the preparation of the beds, amount of seed of different species to be used per seed bed, watering, and shading; the effect of spacing and the methods of preparation of the ground upon the development of the root system.
Districts 2 and 3	To determine whether it is practicable to grow stock near the planting site without watering and much care.
District 4	To determine to what extent small and weak trees can be eliminated from the nursery by the use of seed graded by weight.
District 5	To carry on experiments to determine the proper amounts of seed of different species which should be sown in nursery beds; to determine the depth of cover, the proper seasons and methods for sowing the seed beds, etc.
District 6	Same as above.

Species, methods, and seasons.

Experimental planting:	
District 1—	
Norway spruce, sugar pine, basswood, white ash, shagbark hickory, western white pine, yellow pine, Douglas fir.	To test the suitability of different species to northern Idaho.
District 2—	
Yellow pine	To determine the best method and season of planting in the following subdistricts: Southeastern, northeastern, and in Kansas sand hills.
Scotch pine	To compare the value of Scotch pine for the north slope of the sand hills, and also for the moister sites in the Pikes Peak region; and to determine its relative merits for Kansas sand-hill planting.
Austrian pine	To determine comparative value of Austrian pine for planting on certain areas of the western yellow-pine type, and its relative merits for Kansas sand-hill planting.

A.—FORESTATION—Continued.

Species, methods, and seasons—Continued.

Project.	Object.
Experimental planting—Con.	
District 2—Continued.	
Lodgepole pine.....	To determine the best method and season of planting in the northwestern subdistrict.
Eastern white pine, western white pine, Norway spruce, Norway pine, Japanese larch, sugar maple.	To find species which would be adapted to the moister sites in the Pikes Peak region.
Black locust and honey locust.	To determine relative merits for Kansas sand-hill planting on plowed and cultivated ground.
Engelmann spruce..	To determine the best method and season of planting in the southeastern and northwestern subdistricts.
Douglas fir.....	To determine the best method and season of planting in the southeastern, southwestern, and northeastern subdistricts.
Experimental planting and sowing:[1]	
District 3—	
Western yellow pine.	To test experimentally western yellow pine on a comparatively large scale on different Forests and on different sites. Also to reforest by means of the seed-spot method.
	To determine the best method of planting western yellow pine in pots and with balls.
Douglas fir.....	To test experimentally Douglas fir on a comparatively large scale on different Forests and on different sites; to reforest by means of the seed-spot method; and to determine the best time of planting.
Jeffrey pine	To test experimentally Jeffrey pine on a comparatively large scale on different Forests and on different sites, and to reforest by means of the seed-spot method.
Alligator juniper....	To find a practical way of handling alligator juniper seed and to determine its behavior by the seed-spot method.
Arizona cypress....	To determine the suitability of Arizona cypress for reforestation in Arizona.
Black locust, white elm, green ash, desert willow, honey locust, Russian olive, Norway spruce, limber pine.	To determine the suitability of these species to local conditions and the behavior of less common species in artificial planting.
District 5—	
Sugar pine, yellow pine, Douglas fir, white fir, incense cedar.	To determine the best season and the best methods for sowing and planting important species on favorable and unfavorable sites.
Eucalyptus.....	To determine experimentally the suitability of the less common species to different sites in southern California.
District 6—	
Douglas Fir.....	To determine the best method and season of direct seeding and planting in lower slope type west of Cascade Mountains; on denuded areas within various types in the Siskiyou Mountains; in humid coast region, Siuslaw Forest; and on denuded areas on slope type of Blue Mountain region.

[1] More intensive experiments with testing species, sites, methods, and seasons are listed under specific projects which are to serve as a check on this experimental planting on a large scale.

A.—FORESTATION—Continued.

Species, methods, and seasons—Continued.

Project.	Object.
Experimental planting and sowing—Continued.	
District 6—Continued.	
Western yellow pine	To determine the best method and season of direct seeding and planting on denuded areas within various types in the Siskiyou Mountains; on denuded areas in slope type of northeast Washington; and on denuded areas on slope type of Blue Mountain region.
Sugar pine, Sitka spruce, Scotch pine.	To determine the best method and season of direct seeding and planting on denuded areas within various types in the Siskiyou Mountains; in humid coast region of Siuslaw Forest; and on denuded areas on slope type of Blue Mountain region.
Eastern hardwood species.	To determine the suitability of eastern hardwood species to bottom lands and slope types west of the Cascades, and to a very small extent east of the Cascades.
District 7—	
Loblolly pine.....	Reforestation studies; experimental seeding and planting in cooperation with New Jersey and South Carolina.
Maritime pine.....	Same as above.
Cork oak, shortleaf pine, longleaf pine.	Experimental planting in cooperation with South Carolina to determine the value of the different species for forestation in the southeastern pine belt.
Eucalyptus planting in Florida.	To test the suitability of the different species of eucalyptus to different sections of Florida, in cooperation with the State in the Everglades, and in cooperation with the Tampa Board of Trade at Tampa.
Effect of cultivation upon success of planting.	To determine the influence of cultivation in its relation to ground cover on the success of planting operations.
Stock for field planting—	
Jack pine, yellow pine, Scotch pine.	To determine the best stock (seedling or transplant) for field planting.
Sheep bedding.....	To determine the effect of continuous bedding of sheep on reforestation or natural reproduction.
Aspen cover.....	To determine the effect of aspen cover on the success of sowing with Engelmann spruce and Douglas fir.
Effect of an aspen nurse in Douglas-fir planting.	To determine the effect of an aspen nurse upon the success of Douglas-fir planting.
Comparison of different classes of stock in planting: Douglas fir, Jeffrey pine, yellow pine.	To determine the relative value of different classes of stock for field planting.
Field planting with graded stock.	To determine to what extent better results in field planting can be obtained through careful grading of planting stock.
Effect of holding nursery stock over winter on planting areas upon the success of field planting.	To determine the advisability of shipping nursery stock to planting areas in the fall to be held there until planting operations commence in the spring.

A.—FORESTATION—Continued.

Sites.

Project.	Object.
Habitat extension:	
Yellow pine	To determine the possibility of growing yellow pine in the piñon-juniper type.
	To determine the most successful method and season of sowing on ground bearing a fair stand of seed trees and also open sagebrush parks.
Douglas fir	To determine the possibility of using Douglas fir in the lower part of the Engelmann spruce type.
Planting in parks	To determine the possibility of growing trees in the open parks.
Planting on brush-covered, timberless slopes: (*a*) Yellow pine, (*b*) Douglas fir.	To determine whether it is possible to plant southerly steep slopes covered with oak brush and what species should be used.
Comparison of sites for western yellow-pine planting.	To determine the relative value of different sites for yellow-pine planting in District 3.
Reforestation in bear clover areas.	To determine the best method by which the extensive bear clover areas can be gradually transformed into a forest. Study similar to the brush field study in northern California.
Forest extension into the northern brush fields.	To determine the best method and species to plant in the brush fields of northern California so as to gradually extend the forest into the brush fields which once were a forest.
Planting on pumice soil: Western yellow pine in District 6.	To determine the best method and season of planting western yellow pine on light, pumice soils, east of the Cascade Mountains.

Introduction of exotics.

A study of California exotics of possible economic value in this country.	To determine, by a study of the results obtained by the cultivation of various exotics in California, their possible potential range in this country and their probable economic value, together with data as to conditions best adapted to their success.
Maritime pine	To bring together the available information as to the possibilities of introducing maritime pine as a source of naval stores in this country.
Cork oak	To furnish information as to the possibilities of the cork oak in this country as source of the commercial cork.

Special.

Experimental work in basket-willow culture.	To secure improved varieties of basket willows; to develop better cultural methods in growing willows; to secure better methods and devices in handling rods; to encourage growing of willows on land suited to the purpose.
Development of American species of basket willows.	To secure varieties of basket willows better adapted to American conditions than the European species now grown. Hardiness and continued vigorous growth are the principal characteristics desired.

A.—FORESTATION—Continued.

Special—Continued.

Project.	Object.
Cooperative basket willow growing experiment in New Jersey with the Forest Park Reservation Commission of New Jersey.	To test the possibility of growing basket willows on the cheap sandy lands of New Jersey.
Sand dune control	To test various means of direct reforestation of the sand dunes on the Siuslaw National Forest.
Erosion	To determine the extent to which erosion of a gully may be checked by willow planting.

B.—INFLUENCES.

Effect of forests upon stream flow in Southern Appalachian.	To determine the effect of forest cover upon stream flow and erosion in the Southern Appalachians.
Relation of forest to stream flow.	To keep abreast with the literature on the subject.
A comparative meteorological study of "parks" and timbered areas.	To determine the effect of forest cover upon climate of the area occupied by it, as compared with the open "park."
The influence of a forest cover upon the accumulation and rate of melting snow and upon run-off.	To determine to what extent and in what manner virgin western yellow-pine forests affect the amount of snow reaching the ground, the rate of melting, and the amount of run-off.
Effect of forest cover on stream flow.	To determine the effect of forest cover on run-off and erosion.

C.—MANAGEMENT.

General.

Northeastern hardwoods (beech, yellow birch, and maple).	Silvicultural study with special reference to growth and volume.
Woodlot study for central New York.	To obtain a series of regional woodlot studies.
Second-growth hardwoods in the Hudson River Valley.	Same as above.
Forestry for coal-mine owners.	To furnish information regarding the handling of timber lands for coal mines.
Management of hardwood forests in the Southern Appalachians.	To furnish information regarding the management of the different hardwood species in the Southern Appalachians.
Forest management of the hardwood bottom lands of the southeastern United States.	To suggest system of forest management for the southern hardwood bottom species.

C.—MANAGEMENT—Continued.

Methods of cutting.

Project.	Object.
Effect of different methods of cutting in different types upon growth and natural reproduction, District 1.	To ascertain the best silvicultural system of cutting in western white pine, western larch, and western yellow-pine types.
Methods of cutting, District 2:	
Lodgepole pine	To determine the effect of various methods of cutting in mature lodgepole pine stands in inducing reproduction.
Balsam type.....	To determine a method of cutting which will favor spruce reproduction over balsam in mixed stands of these two species.
Mixed lodgepole pine and Engelmann spruce types.	To determine the method of cutting most likely to favor Engelmann spruce reproduction where it occurs in mixture with lodgepole pine.
Results of different systems of marking, District 3.	To determine the comparative merits of one system of marking over the other.
Effect of seasons and methods of cutting in woodland type, District 3.	To determine the conditions under which the cutting in woodland type results in best regeneration of the stand. Coronado Forest.
Different methods of marking and cutting, District 4:	
Idaho yellow pine.....	To determine the best method of cutting in the Idaho yellow-pine forest.
Aspen in Utah.....	To determine the best methods of cutting in aspen stands.
Effect of different methods of cutting upon natural reproduction in Jeffrey pine, sugar pine, mixed type of yellow pine, Douglas fir, and white fir.	To determine the best method of cutting upon natural reproduction and growth of remaining stand.
Methods of cutting in the yellow pine and Douglas fir types, District 6.	To determine the best method of cutting in Douglas fir and yellow pine so as to secure natural reproduction and the best growth of the remaining trees.
Cut-over areas:	
District 1.....	To determine the conditions under which natural reproduction takes place on areas cut-over under different conditions as a basis for proper silvicultural handling of timber sales.
District 3.....	To determine rate of growth and loss, rate of regeneration and effect of various factors upon regeneration.
District 5.....	Same as above.
District 6.....	To determine the progress of natural reproduction on cut-over areas.
Felling snags and diseased trees.	To determine the actual cost of felling snags and diseased trees, as means of improving condition of the Forest, and to ascertain its bearing upon the establishment of stumpage rates.

C.—MANAGEMENT—Continued.

Brush disposal.

Project.	Object.
Effect of scattering brush after logging upon reproduction, District 3.	To determine the effects of scattering the brush after logging upon reproduction in western yellow-pine stands.
Brush disposal:	
District 4, Idaho yellow pine.	To determine the effect of different methods of brush disposal upon natural reproduction.
District 5.....	To determine the cost and method of brush disposal.
	To determine the effect of the removal of brush upon the development of seedlings.
District 6.....	To determine the effect of brush disposal upon natural reproduction.

Natural reproduction.

The loss of seedlings in the forest during the early stages of development.	To determine the rate of loss of seedlings during the early stages of development and the factors responsible for it.
Reproduction on burns.....	To determine the progress of reproduction on burned-over areas.
Pole and sapling competition.	To determine the competition between the various species and to observe the replacement of brush on an adjoining south slope.

Thinnings.

District 2:	
Yellow pine.....	To determine the effect of different degrees of thinning in young yellow-pine stands.
Lodgepole pine.....	To compare the rate of growth and increment of the trees left after thinning with the increment on new stands obtained by clear cutting.
	To determine best degrees of thinning in sapling lodgepole-pine stands.
	To determine the effect of thinning from beneath and thinning from above.
	To determine the best density in lodgepole sapling stands about 40 years old.
Douglas fir and Engelmann spruce.	To determine effect of different degrees of thinnings in young stands.
District 4:	
Aspen in Utah.....	To determine the effect of thinning upon the remaining stand.
District 5:	
Douglas fir.....	To determine the effect of thinning upon the growth of the remaining stand.
Mixed yellow pine, white fir, and incense cedar.	To determine the comparative merits of different degrees and frequency of thinning.

C.—MANAGEMENT—Continued.

Valuation.

Project.	Object.
Valuation of young growth with reference particularly to fire damage.	To determine the value of young growth with particular reference to fire damage.
Valuation of land for agricultural and forest uses.	To determine the value of land for agricultural and forest uses.

D.—MENSURATION.

Volume, growth, and yield:	
District 1—	
Douglas fir, larch...	To secure data on growth, volume, and yield.
Lodgepole pine.....	To secure data on volume, growth, and yield for the less favorable sites on the Deerlodge Forest.
Western white pine, western yellow pine.	To secure growth, volume, and yield data.
District 2—	
Lodgepole pine.....	To construct volume tables which will be of value for more than simple local use. To obtain data for the construction of growth and yield tables.
Western yellow pine.	To construct volume tables which will be of value for more than local use. To obtain data for the construction of growth and yield tables.
Engelmann spruce..	To construct volume tables which will be of value for more than local use.
Growth of western yellow pine stands before and after cutting, District 3.	To determine the growth for stands before and after a selection cutting; also a comparison of the different methods of determining the growth percentage before and after cutting.
Growth, volume, and yield studies, District 4.	
Yellow pine in Idaho...	To secure growth, volume, and yield data as a basis for management of Idaho yellow-pine forests.
Aspen in Utah.....	To secure growth, volume, and yield data of aspen as a basis for the management of aspen stands.
Solid contents of cord wood, District 5.	To ascertain the actual solid contents of cord wood as a basis for estimating timber for pulp wood.
Growth and yield, District 6.	To determine the effect of various conditions of soil density upon the growth of stands in different types.
Fundamental laws of tree growth and comparative rapidity of growth of forest trees, District 7.	To establish the general relationship between the various geometrical characteristics of trees which would enable us to develop quick methods of determining the volume and yield of standing trees and forests and to furnish a basis for comparing different species as to their growth and development.
Mill scale studies, in cooperation with the Branch of Products:	
Douglas fir.....	To determine the percentage of clear and common lumber obtained from each grade of Douglas-fir logs in the Columbia River and Puget Sound regions.
Blue gum.....	To obtain a mill tally of blue-gum logs.

E.—PROTECTION.

Fire.

Project.	Object.
Methods of fire protection...	To determine the best methods of fire protection.
Progress of the States in forestry and fire protection, and digest of State forest and fire laws:	
Forest fires in the United States and Canada.	To ascertain the causes of forest fires, such as lightning and other climatic causes, extent of damage, together with historical data concerning the large conflagrations.
Recovery of chaparral from fire.	To determine the after effects of fire, and the number of years necessary to reestablish a chaparral cover.
Growing green firebreaks.	To maintain firebreaks by growing mesembryanthemum and similar fire resistant species to the exclusion of chaparral.
Effect of light burning..	To determine the effect of frequent light burnings upon the forest.
Fire damage in mature timber.	To determine the effect of fire upon the growth of mature timber.
Influence of grazing in preventing damage by fire.	To determine the value of grazing (1) in preventing forest fires; (2) in decreasing difficulty of fighting fires.

Grazing.

Effect of grazing on the reproduction of western yellow pine, and plan of management for grazing on yellow-pine lands in District 3.	To determine the amount and severity of damage, and to collect information to use as a basis for proper management of grazing in the yellow-pine type of the Southwest.
Management of grazing in the yellow-pine type in District 4.	To secure authentic information upon which to base definite management of sheep grazing on approximately eight million acres of yellow-pine land in District 4.
Effect of grazing on tree reproduction.	To determine (1) the percentage of seedlings injured by sheep, cattle, and goats for each species of locality; (2) relation of intensity of injury to intensity of grazing, season of grazing and method of handling; (3) the ultimate damage to timber from each of the various kinds of injury; and (4) possibility of eliminating damage by more careful management of grazing.
Effect of grazing on growth and reproduction of aspen in Utah.	To determine the effect of grazing sheep upon the sprouting and ground cover of aspen.
Recuperation of different tree species from injuries by grazing.	To determine definitely the time and character of the injury and the ultimate economical effect of the injury upon tree growth.
Effect of grazing on the reduction of fire risk.	To determine to what extent grazing reduces the fire danger in the forest.
Effect of sheep grazing on yellow-pine reproduction.	To ascertain the effect of sheep grazing, if any, in determining the germination of yellow-pine seed as a basis for the use of sheep grazing as means of artificial and natural reforestation, and as a basis for a grazing policy on cut-over areas.

E.—PROTECTION—Continued.

Diseases.

Project.	Object.
Nursery diseases:	
District 2	To determine the methods of checking fungous diseases of stock in nurseries.
District 3	To determine the best methods of preventing damping-off in seed beds.
Pathological investigations, District 5.	To determine the age of infection of incense cedar by *Polyporus amarus* (dry rot); the age of infection of white fir by *Echinodontium tinctorum;* the relation of decay to fire and lightning wounds; the nature and extent of damage done by needle diseases in yellow pine, Jeffrey pine, white fir, and red fir.
Root mould in transplant beds.	To determine the cause of mould on roots of the transplants of yellow pine.
Effect of mistletoe upon growth and seed production of western yellow pine.	To determine the effect upon the soundness of western yellow pine.
Decadence of white fir on the Crater Forest.	To determine (*a*) underlying cause of the rot, (*b*) size of the trees affected, (*c*) rapidity of the decay, as a basis for a timber-sale policy with regard to white fir.
Decadence of mature western yellow pine.	Work begun 1910. To determine the decadence of western yellow-pine trees left as seed trees on timber-sale areas.

Insects.

Insect attacks on cupped western yellow pine.	To determine the susceptibility of cupped trees to attacks by insects.

Animals.

Methods of combating seed-destroying animals.	To determine the best methods of eliminating seed-eating animals from the sown areas.

Snow.

Damage to reproduction by snow.	To determine the effect of snow upon reproduction.

F.—REGIONAL STUDIES.

Forest conditions in Porto Rico.	To describe the forest resources together with discussion of forest problems.
The forests of Florida [1]	Same as above.
The forests of Mississippi and Alabama.[1]	Same as above.
The forests of North Carolina.[1]	Same as above.

[1] To be correlated with the wood-using industries of the products.

G.—SILVICAL STUDIES.

Distribution.

Project.	Object.
Forest regions of the United States with special reference to laws of distribution.	To find a scientific basis for the classification into forest regions; to determine their relation to the climate, physiography, and geology of the country and on the basis of such detailed description determine general laws of distribution.

Forest types.

Meteorological observations..	To determine the general climatic characteristics of the region and the ecological site differences of yellow pine-Douglas fir type, larch type, and white-pine type.
Meteorological study of conditions on north and south slopes of Douglas-fir types and in Engelmann-spruce types.	A comparison of the meteorological factors typifying these types.
Meteorological study of conditions in the yellow-pine, Douglas-fir, and Engelmann-spruce types.	A comparison of the meteorological factors typifying the yellow-pine, Douglas-fir, and Engelmann-spruce types.
Meteorological observations..	To determine the general climatic characteristics of the region and the ecological site differences of the three most important forest types: (*a*) Jeffrey pine, (*b*) sugar pine, (*c*) mixed type of yellow pine, Douglas fir, and white fir.

Special.

Phenological observations...	To secure data on leafing, flowering, seed ripening and dissemination, and leaf falling of the principal forest trees, for technical use for charts to be prepared for schools.
Establishment of arboretum in Rock Creek Park.	To develop an arboretum of American species of trees not native to the District of Columbia and of exotic species and to establish a salicetum for the purpose of identification and hybridization.
Relation of soil to tree growth.	To determine the soil requirements of the different species and the methods of determining the soil requirements of forest trees.
Forest experiments at Cloquet Station, Minn., in cooperation with the University of Minnesota.	To be used as demonstration grounds for securing silvical data to be used in Service publications.
Permanent sample plots; white pine, mixed hardwood, coppice, red spruce, red pine, white ash, Douglas fir, Scotch pine, loblolly pine, chestnut, European larch, Norway spruce balsam fir, birch, beech, and maple; scrub pine, Austrian pine, pitch pine, hemlock, European fir, lodgepole pine, Alpine fir, western yellow pine, western white pine, sugar pine, and white fir.	To obtain accurate quantitative figures on growth and yield, reproduction, and other silvicultural characteristics.

II.—SPECIAL.

Project.	Object.
Forest taxation in Washington.	To determine a just basis for taxing timberlands in Washington.

I.—TREE STUDIES.

Ashes in the eastern United States.	To ascertain the silvical characteristics, present stand and utilization, and management of second-growth stands of ash in the eastern United States, with special reference to white ash.
Bald cypress, with special reference to its reproduction, growth, and management.	To determine whether natural reproduction of cypress can normally be expected, the rate of growth of second-growth stands, and the best system of management for both virgin and second-growth stands.
Balsam fir	To determine the growth, volume, and yield of balsam fir, its silvicultural characteristics, and the best method of management for the production of pulp wood.
California red fir (*Abies magnifica*).	To bring together all the available information on the distribution, growth, management, and uses of this species.
Cottonwood in the lower Mississippi Valley.	To collect yield data for second-growth cottonwood, to study the characteristics of species, and suggest methods of management.
Douglas fir	To supplement work done in 1909 by extending the study to poorer qualities of soils, as a basis for estimates of the potential yield of the National Forests in the Douglas-fir region and for determining the value of certain land for forest purposes.
Eastern hemlock	Monograph on hemlock, including its history, biology, and management. One of the original series of monographs planned by Dr. B. E. Fernow, of which white pine and southern pines are samples.
Eucalyptus study	To determine the possibilities of the different species of eucalyptus for planting, their yield and management.
Incense cedar	To bring together all the available information on the distribution, growth, management, and uses of this species.
Jack pine	To bring together available information on the distribution, qualities, and uses of the jack pine.
Loblolly pine in North Carolina (in cooperation with North Carolina).	To ascertain the yield of second-growth stands and to suggest methods of management.
Loblolly - pine mill - scale study (in cooperation with North Carolina Geographic and Economic Survey).	To collect data on second growth of loblolly pine for a graded mill-scale table and volume table; to complete Ashe's report on loblolly pine in North Carolina and to secure data to complete Sterrett's monograph on loblolly pine.
Lodgepole pine	To bring together available information on the distribution, qualities, and uses of lodgepole pine of Montana and Idaho.
Longleaf pine with reference to turpentine industry.	To bring together all available information on the growth, volume, yield, and management of longleaf pine with special reference to the turpentine industry.
Red pine	To bring together all available information on the growth, volume, yield, and management of red pine throughout its entire range.
Shortleaf pine	Revision and extension of report on shortleaf pine in Virginia.

I.—TREE STUDIES—Continued.

Project.	Object.
Sugar pine [1]	To bring together all the available information on the distribution, growth, management, and uses of this species.
Western white pine	To secure all available information on the distribution, growth, and management of western white pine as a basis for a monograph on this species.
Western yellow pine in Oregon.	To bring together all the available information on the growth, yield, and management of western yellow pine in Oregon.
White pine of Montana and Idaho, exclusive of *Pinus monticola*.	To bring together available information on the distribution, qualities, and uses of the white pines of Montana and Idaho.
White pine under forest management.	To supply better organized data, with more specific application to management.
Second-growth yellow pine	To determine the yield and possibilities of management of the extensive stands of pure yellow pine coming in as a result of early cuttings on the Stanislaus and Tahoe Forests.
Red spruce in the Northeast.	To obtain full information regarding the silvical characteristics and utilization of red spruce, with special reference to the management of second-growth stands.
Silvical leaflets	Bringing together in a brief form the available silvical information regarding American forest trees.
Western larch	To bring together available information on the distribution, qualities, and uses of western larch.
Western red cedar	To bring together all the available information on growth, yield, and management of western red cedar.
Willows, their economic uses and importance.	To secure data on the botanical and silvical characteristics, their management.
Second-growth yellow poplar.	To determine the silvical characteristics of second-growth yellow poplar, with special reference to systems of management to be used in such stands.
Western hemlock (*Tsuga heterophylla*).	To secure additional data for revising and reprinting information and tables on western hemlock as found in Bulletin 33 of the Forest Service.

J.—UTILIZATION.

Lumbering in National Forest regions.	To secure reliable data on cost of logging and a basis for uniform methods of stumpage appraisals.
Flume construction and fluming.	To describe methods of flume construction, costs, and operation.
Deterioration of timber caused by fires.	To determine the rate with which timber deteriorates for merchantable use.
National Forest timber sales.	To state the policy and indicate the opportunities for the purchase of timber from the National Forests.

[1] The completion of this monograph should be made in cooperation with the Branch of Products.

Issued April 25, 1913.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.
HENRY S. GRAVES, Forester.

REVIEW

OF

FOREST SERVICE INVESTIGATIONS.

VOLUME II.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE.

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ALBERT F. POTTER, *Associate Forester.*
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Issued April 25, 1913.

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1913.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., November 8, 1912.

Sir: I have the honor to transmit herewith Volume II of the Review of Forest Service Investigations, and to recommend its publication.

Very respectfully,

Henry S. Graves, *Forester.*

Hon. James Wilson,
Secretary of Agriculture.

The Review of Forest Service Investigations is issued at intervals as sufficient material accumulates. It is designed to furnish periodically a résumé of the character and progress of the investigative work conducted by the Forest Service. Each issue will contain brief accounts of the progress made on the more important studies whose completion may require several years, and more detailed reports on minor projects whose publication in separate form is inadvisable. Similar material furnished by State foresters will be published from time to time.

It is the purpose of this Review to keep all of the men engaged upon investigative work in touch with each other. The fresh results of each study as it develops will be reported, and a medium furnished for the interchange of scientific data and ideas.

The Review deals largely with matters on which the Forest Service can not yet speak authoritatively, and the publication of the views presented does not imply that the Forest Service assumes full responsibility for them.

LABORATORIES AND FOREST EXPERIMENT STATIONS OF THE FOREST SERVICE.

Forest Products Laboratory (in cooperation with the University of Wisconsin), Madison, Wis.

Ground Wood Laboratory, Wausau, Wis.

Wood Testing Laboratory (in cooperation with the University of Washington), Seattle, Wash.

Priest River Experiment Station on the Kaniksu National Forest, Priest River, Idaho.

Cloquet Experiment Station (in cooperation with the University of Minnesota), Cloquet, Minn.

Fremont Experiment Station on the Pike National Forest, Manitou, Colo.

Wagon Wheel Gap Experiment Station on the Rio Grande National Forest, Wagon Wheel Gap, Colo.

Fort Valley Experiment Station on the Coconino National Forest, Flagstaff, Ariz.

Utah Experiment Station on the Manti National Forest, Ephraim, Utah.

Feather River Experiment Station on the Plumas National Forest, Quincy, Cal.

Seed Testing Laboratory and Willow Holt Station, Office of Silvics, Arlington Farm, Washington, D. C.

Dendrological Laboratory, Office of Dendrologist, Washington, D. C.

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DENDROLOGICAL INVESTIGATIONS.

STUDIES IN IDENTIFICATION OF NORTH AMERICAN FOREST TREES.

BIENNIAL FRUCTIFICATION OF ALASKA CYPRESS.

(*Chamæcyparis nootkatensis.*)

GEORGE B. SUDWORTH, *Dendrologist.*

Our native cypresses fall naturally into two groups, Cupressus and Chamæcyparis. Authors differ as to the maintenance of Cupressus and Chamæcyparis as distinct genera, some placing all species under Cupressus and considering Chamæcyparis a subgenus or section only of Cupressus, while those who hold Cupressus and Chamæcyparis to be distinct genera divide our species as follows:

Cupressus macrocarpa.	Chamæcyparis thyoides.
Cupressus arizonica.	Chamæcyparis nootkatensis.
Cupressus glabra.	Chamæcyparis lawsoniana.
Cupressus macnabiana.	

Whether held to be distinct genera or not, each of these groups has fundamentally distinct characters shown in the size of the cones and in the form and number of the seeds borne by its species.

The species grouped above under Cupressus have characteristically large, long-persistent cones [1] which produce numerous seeds under each scale, and the seeds have no membranous wings. These cypresses are further characterized by their biennial fructification. Strongly contrasted with these characters are those of the cypresses that may be included under Chamæcyparis, which produce small early decidu-

[1] Cones of these cypresses remain attached to the branches for from 5 to 10 or more years, and often without liberating their seeds.

ous cones,[1] and not over 5 membranous-winged seeds are borne under each cone scale. These cypresses are all held to have annual fructification.

In reference, however, to the annual fructification of the species of the Chamæcyparis group, recent investigations by the writer show that annual maturation is not common to all of this group of species, the Alaska cypress being an exception in requiring two years to mature its fruit. Indications of this fact had been observed for a number of years, though the writer was unable to obtain positive proof of it until the early spring of 1912, when Forest Supervisor W. G. Weigle collected specimens on the Chugach National Forest in Alaska which fully verify this belief, at least in so far as the Alaskan forms of the species are concerned. Whether or not to meet the short growing season in Alaska this species has developed a biennial fruiting form at the far North, as contrasted with an annual fruiting one in the southern part of its range, where there is a relatively longer growing season, is yet to be determined. For the present, however, this discovery makes it impossible further to include annual and biennial fructification as generic or subgeneric characters distinguishing Cupressus and Chamæcyparis.

The accompanying illustration (plate I) shows (a) the conelets just developed from pistillate flowers opened the early spring of 1912; (b) the 2-year-old seed-bearing cones due to mature the autumn of 1912; and (c) empty cones that matured and shed their seed the autumn of 1911.

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[1] Cones of this group commonly shed their seeds and fall from the trees within one or two years after they are ripe.

BRANCHLETS SHOWING BIENNIAL FRUCTIFICATION OF YELLOW OR ALASKA CYPRESS (CHAMÆCYPARIS NOOTKATENSIS); *a*, CONELETS OF FIRST SEASON; *b*, NEARLY MATURE CONES OF SECOND SEASON; *c*, EMPTY CONES 2 YEARS OLD.

(Two-thirds natural size.)

GRAZING INVESTIGATIONS.

STUDIES IN ARTIFICIAL RESEEDING.

INTRODUCTION OF FORAGE PLANTS.

FORT VALLEY EXPERIMENT STATION.

G. A. Pearson, *Forest Examiner.*

OBJECT.

The introduction of forage plants with a view toward improving range conditions.

LOCATION.

All of the areas are within a mile of the experiment station building.

OPEN PARK.

The area is situated well out in a large "park" or treeless area covering about 3 square miles. The area sown covers 13 acres, about one-third of which is wet meadow and the other two-thirds well drained agricultural land. The soil is a deep sandy to clayey loam, with very few rocks. Near-by cultivated fields, with soil similar to that of the better drained portion of this area, produce heavy crops of oat hay or wheat hay without irrgation. The higher land is occupied by bunch grasses, and the low, wet land mainly by low sedges and rushes. Only in the very wet situations does the mature vegetation form a turf, and even here this has been broken by heavy grazing.

FOREST.

This area is situated in a pure western yellow-pine forest cut moderately about 1894. The altitude is approximately 7,300 feet. The soil is a sandy to clayey loam, very rocky and underlain by adobe. The ground cover consists of a sparse growth of grasses with a good but not heavy growth of broadleaf annuals. One of the principal grasses is a native species of Bromus. Owing to heavy grazing the native vegetation at the time of sowing was not sufficiently dense to interfere with the establishment of new species.

FIELD.

In the park, adjacent to the park area already described, the land is low, and remains wet until the middle of May, but is considered

excellent for agricultural purposes. The area was plowed for the first time in 1908, and has been replowed each year since then.

PASTURE.

Situated in the park, elevation 7,250 feet. The land is very similar to that of the park area described above, except that the native vegetation is sparser, owing to heavier grazing. The commonest plants are larkspur, Potentilla, rushes and sedges, with an admixture of grama grass in the drier situations.

OPERATIONS.

Time of sowing:

1909—

Summer—

July 21–23. Kentucky blue grass, orchard grass, brome grass, red top, Italian rye grass, and timothy—park area.

August 6. Orchard grass, brome grass, and Italian rye grass—forest area.

August 25–26. Alfalfa, Turkestan and ordinary—field.

Fall—November 16. Kentucky blue grass, brome grass, Italian rye grass, orchard grass, red top and timothy.

1910. Summer—July. Timothy, alfalfa and brome grass—field.

1911—

Spring—May. Timothy and alfalfa.

Summer—August. Kentucky blue grass, brome grass, and Italian rye grass—pasture.

WEATHER AND SOIL CONDITIONS.

The most favorable time for germination is during the summer rainy season, from July to September. At this time of the year, showers fall almost daily, keeping the surface soil moist almost continually. At other times during the growing season, even though there may be an abundance of moisture in the lower soil strata, the surface is dry, with the result that small seeds which can not be covered deeply fail to germinate, or if they do germinate, die from exposure to drought.

Much damage results to tender plants from soil heaving in late fall and early spring, when the ground is bare of snow.

A very trying time for all young plants is during the spring and early summer months from April to July, during which period there is practically no rainfall.

Killing frosts occur in the park (more so than in the forest) during every month of the year excepting July and August.

SEED.

All of the seed, excepting the brome grass and Italian rye grass, which were purchased locally, was obtained from a seed company of Denver, Colo.

Tests made in the Bureau of Plant Industry at Washington gave the following results:

Seed.	Duration of test.	Germination.
	Days.	*Per cent.*
Orchard grass	13	86.5
Red top	8	87.7
Brome grass	8	74.0
Italian rye	8	48.5
Alfalfa: Turkestan	7	80.5
Ordinary	.....	91.5

METHOD.

In all of the sowings, except in the plowed field and in the pasture, a plot of one acre was sown to each species. The plot was divided into three equal strips, each of which was treated, respectively, as follows:

1. Harrowed with a spring-tooth harrow before sowing; seed broadcasted, and covered with a brush drag.
2. Harrowed with a spring-tooth harrow before sowing; seed broadcasted; no covering.
3. Seed sown on unprepared ground; no treatment of any kind.

In the sowing on plowed ground the field was plowed, harrowed, and dragged before sowing the seed. The seed was sown broadcast and covered by a light harrowing.

The sowing in the pasture was done on unprepared ground. The area was gone over with an ordinary steel harrow, after sowing, but owing to the roughness of the land this had little effect.

RATE OF SOWING.

All of the seed was sown at the rate of 20 pounds per acre, with the following exceptions: Summer 1909, timothy, 18 pounds; fall 1909, brome grass and Italian rye grass, each 25 pounds.

PROTECTION.

The areas, with the exception of the pasture, are all fenced against grazing animals.

RESULTS.

KENTUCKY BLUEGRASS, ORCHARD GRASS, BROME GRASS, ITALIAN RYE GRASS, AND RED TOP—1909.

Methods 1, 2, and 3; park and forest areas; 1 acre of each species in each sowing, sown in summer and fall of 1909. Fairly good germination resulted from the summer sowing under methods 1 and 2,

but the seedlings died during the late fall and spring as a result of frost heaving and drought. The only plants now remaining are a few tufts of Kentucky bluegrass along a wash.

TIMOTHY—1909.

Methods 1, 2, and 3; park area; 1 acre sown in summer and fall of 1909. Germination from the summer sowing was excellent under method 1, good under method 2, and fair under method 3. No germination resulted from the fall sowing. At the present time there is a good stand under methods 1 and 2, but only in the very wettest situations where water stands on the surface until late in the spring. On even moderately wet ground the stand is poor, while where the drainage is good scarcely a spear of timothy is to be found. Where the seed was sown under method 3 the stand in the wettest situations is uneven, with practically nothing in the drier situations. During the past two seasons the timothy has gone to seed, but it does not reach a height of more than 18 inches. In the latter part of May, 1911, it froze back badly.

ALFALFA—1909.

Two varieties were sown—Turkestan and the ordinary alfalfa. The land was plowed in the spring and the seed sown in August. Good germination resulted. In the following spring the stand was considerably thinner than in the preceding fall. Growth was slow, and the plants froze back repeatedly. By June only occasional patches of either variety remained. The loss is attributed to heaving in early spring and frosting and drought in late spring.

ALFALFA, TIMOTHY, AND BROME GRASS—1910–11.

This area, with an additional area of 3 acres, was replowed and sown to these three species in July, 1910. The area given to each species was approximately $1\frac{1}{3}$ acres. All three species came up well in two or three weeks after sowing. In September grasshoppers appeared, and by the latter part of October practically everything was eaten to the ground. By April 15, 1911, all the species had disappeared.

After the failure of this sowing the area was disked and resown to alfalfa and timothy early in May.

Turkestan alfalfa is supposed to be very hardy, but experiments at the South Dakota Experiment Station show a great variation with the locality in which it is grown.

The soil was in excellent condition, with abundant moisture at a depth of 2 inches, but the surface layer occupied by the seeds dried out, with the result that germination was poor, and the young plants died within a week after they came up.

After the failure the area was sown to oats, which came up promptly, showing the advantage of a large seed which can be planted deeply.

CONCLUSIONS.

All of the species sown under range conditions proved to be failures. The establishment of timothy is of little consequence for range purposes, because it succeeded only in wet conditions, which are rarely found on the range in this region.

Timothy, alfalfa, brome grass, and perhaps some of the other species could probably be established through persistent efforts by plowing the ground and sowing during the summer season. The failure of these species in the summer of 1910 was due to grasshoppers, which ordinarily are not sufficiently abundant to cause serious trouble. As a matter of fact there are several patches of brome grass in fields in the valley, although the stand is too sparse to produce a hay crop. Red top and blue grass are known to grow in the vicinity where abundant moisture is available.

It is not believed that the introduction of any of these species, either under range conditions or under cultivation, is practicable. Native grasses are hardier, and if given equal chances will produce more forage on the range than any of these species. While they might succeed under cultivation, it is doubtful whether any of the species would produce as heavily as oats or wheat, which now yield from $1\frac{1}{2}$ to 3 tons of hay per acre without irrigation.

RECOMMENDATIONS.

The test, as far as the range conditions in the vicinity of Fort Valley are concerned, is regarded as conclusive, but it is desirable to test other species which are especially promising. However, the introduction of exotics should not be attempted until it has been ascertained after a careful study of their native habitats that they are likely to succeed in this region. Even in the case of exotics which give great promise of success care should be exercised in selecting a site which will conform as closely as possible to the optimum conditions under which the plants grow naturally.

Since many native plants of high forage value have been proved to be adapted to this region, they should be given the preference in reseeding experiments.

Further experiments under intensive cultivation are not recommended, because such methods are not applicable to range conditions.

COLLECTION AND SOWING OF ALFILARIA SEED.

(*Erodium cicutarium.*)

SEQUOIA NATIONAL FOREST.

ARTHUR W. SAMPSON, *Plant Ecologist.*

OBJECT.

The object of this study was to determine (1) the most effective method of collecting seed of the well-known and preeminent forage plant, alfilaria, in a locality where it grows naturally, and (2) the best methods and time of sowing in situations where it does not occur naturally but where the soil and climatic conditions appear favorable to its growth.

LOCATION.

The study was begun in 1909 in June, the time at which the seed crop usually matures, the collecting being done on the Sequoia National Forest in south central California.

METHODS AND OPERATION.

Methods of collecting the seed varied in accordance with:

1. The density of the alfilaria plants and the degree of maturity of the seed crop.
2. The presence or absence of other plants whose seeds mature at the same time as alfi aria.
3. The character of the soil.

Where the alfilaria stand was dense and pure, the seed was gathered both by hand (picking it with the thumb and fingers where it had accumulated in little bunches) and by combing or raking it together. Where the plants were not fully matured and all the seeds had not been disseminated, collecting by hand was the only practical means. The plants when immature are not easily broken at the crown, and if pulled up the roots come with them. This disturbs the surface soil and covers the seeds which usually accumulate in the depressions on the surface. On areas of immature plants, therefore, the most economical way was to hold the plant aside with one hand and with

the other pick the seeds where they had accumulated. No attempt was made to collect immature seeds.

In the case of fully matured plants, where the stand was pure, or nearly so, the part of the plant above ground was entirely removed. When thoroughly dry they separate readily at the surface of the ground and a relatively large area can be cleared in a short time by the use of a rake. After clearing, an improvised "seed comb," resembling a rake but with shorter teeth and a handle a foot long, was used in gathering the seed in a pile. By this method, however, many leaves and broken off style branches are usually gathered with the seed, while small seed may be left ungathered.

It is rather exceptional to find large tracts (except in plowed or cultivated fields) where alfilaria occurs in pure and dense stand. In the natural habitat where the soil has not been disturbed, it is almost invariably associated with red foxtail (*Bromus rubens*) and wild barley (*Hordeum jubatum*) whose seeds ripen simultaneously with those of alfilaria. In such situations the rake was not entirely satisfactory.

The character of the soil was also a factor in collecting. The stiff clay loam or "adobe," the type to which alfilaria is locally best adapted, becomes extremely dry and hard in the latter part of May, and bakes and cracks open. In some instances cracks had formed in the ground from about a half inch to 5 inches wide, and from a few inches to several feet in depth. In such places the seed was collected by hand as well as by means of the seed comb.

The cost of the seed collected was approximately 50 cents per pound, while on the market seed of equally high viability usually sells at $1 per pound.

VIABILITY OF THE SEED.

A highly important fact was learned concerning the germination power of the seed. While the seed collected was plump and fully developed, germination tests made in June, immediately after the seed had been disseminated, showed a viability of only from 4 to 9 per cent. Despite the fact that various diurnal and nocturnal temperatures were applied in the germination chamber, no sample tested at that time showed a 10 per cent viability. Additional tests were made in the autumn after the seed had been kept in a cool, dry place for several months, and the viability was found to be the same. Late in the autumn, however, small samples of the seed were collected in the natural habitat where it had been exposed to the season's wind, sun, and atmospheric moisture. Contrary to expectations 96 out of a possible 100 per cent germinated. Experimentation

with the seed collected in June proved that the apparent low viability was due to the thick and horny seed coat. When the seed coats were clipped a germination of from 80 to 98 per cent was obtained. The exact physiological effect of the weather on the seed is not known, but it apparently has much to do with the hardness of the seed coat.

From these tests it was evident that in order to get strong germination from autumn seeding the seed must be subjected to the summer weather, otherwise it will lie over one season and possibly decay. To avoid the delay of a season's growth, the seed may be placed in a thin layer in a wire screen vat, as protection against rodents and stock, and so located as to receive the benefit of the climatic conditions before it is used for seeding.

RECOMMENDATIONS.

Seed collecting.—In case large quantities of alfilaria seed are desired, the cost of collecting may be greatly reduced if small areas in the region where this plant grows naturally are plowed and seeded. The lands should be plowed about 6 inches deep in the fall, when conditions become favorable for such work, and thoroughly harrowed before and after seeding. The cost of preparing and seeding an acre should not exceed $7. In addition to furnishing an ideal place for collecting alfilaria seed, owing to the smooth surface, the lack of weeds, etc., such an area would afford an ideal place to study the propagation and habits of the species. The well-pulverized surface would no doubt render the soil more retentive to moisture than on the open range, and would at least delay, if not prevent, the breaking and cracking of the soil.

Seeding for forage.—Eight pounds of seed should be sown per acre to insure a satisfactory stand. Since alfilaria is an annual plant it should not be grazed too closely before the seed crop has matured.

In selecting the area to be sown it should be kept in mind that the habit of growth of this plant is semiprostrate, and that its maximum height is about 12 inches. Accordingly, the area selected should not be one which supports a stand of native vegetation, such as will completely outgrow and overshadow the alfilaria plants. Then, too, alfilaria is an exceedingly drought-resistant plant, and therefore moist meadows, swales, and all habitats of high water content should be avoided. The drier, warm south and west exposures are much more favorable. Elevation is also of high importance. In California this plant does not make a satisfactory growth for forage above an elevation of 5,000 feet. Seed should not be sown in the northern States above 3,000 feet.

The most suitable time to scatter the seed will depend upon the location, the climate, and the character of the area to be seeded. If there is sufficient moisture in the soil to insure immediate germination so that the resulting seedlings will be large enough by winter to withstand the inclement weather, early fall seeding is recommended. On the other hand, if the fall rains come late and the weather is backward, the seed should not be scattered until the first permanent winter snow comes, so that no germination will take place until spring. Late fall seeding is preferable to sowing in the spring, as the seedlings invariably get an earlier start.

As the style branches, whose function it is to work the seed into the ground, are for the most part broken off by handling, it will be necessary to give the soil some light treatment after seeding in order that the seed may get beneath the soil surface. An ordinary tooth harrow will serve the purpose, or if the ground happens to be rough and rocky a brush harrow pulled over the area by a saddle horse will be found effective, provided the native vegetation does not bind the soil too tightly. In that event, sheep driven over the area in a compact body will do the work of a harrow.

STUDIES IN FOREST PROTECTION.

RELATION OF GRAZING TO TIMBER REPRODUCTION.

SHASTA NATIONAL FOREST.

ARTHUR W. SAMPSON and WILLIAM A. DAYTON, *Plant Ecologists.*

OBJECT.

The object of the investigation is to determine, from a silvicultural standpoint, the amount and seriousness of injury due to grazing; the season of greatest injury; the relative damage to the various economically important tree species; the actual extent of injury from both browsing and trampling; under what conditions grazing may aid aid forest reproduction, and the policy which should be adopted to govern grazing in different types of forest.

LOCATION.

The study was started in the spring of 1911 on the Shasta National Forest. There are 7 fenced areas and 43 sample plots, 12 of which are in the fenced areas, while the remaining 31 are unprotected from stock. These plots represent 7 different ranges; 14 on cattle range, 22 on sheep range, and 7 on goat range.

METHOD AND OPERATIONS.

Effort has been made to embrace all the main ecological conditions under which the timber species propagate locally. Plots have been laid off on slopes and level areas; in canyons and at edges of parks; to include reproduction protected in part or entirely by older growth; reproduction in fenced and unfenced areas, in localities of abundant and sparse forage cover, etc. Six areas of one-half acre each and another area an acre in extent were fenced against stock; two of these are on cattle range, two on goat range, and three on sheep range. These fenced plots will aid in determining whether or not grazing promotes the establishment of a timber stand by exposing the soil and by trampling and harrowing the seed into the ground, and will make it possible to compare the extent of recovery from grazing injuries of timber reproduction on the open range and on protected range, other conditions being identical.

Each plot is permanently staked, and a "tie" is made locating it with reference to an established survey corner. The stake at the

northeast corner of each plot is scribed with the plot number. The plots average about 12 feet in width. Where wider plots seem advisable they are subdivided into widths convenient for recording the data. The length averages about 50 feet, the average area of the plots being 670 square feet. The plots contain from 28 to 1,194 living seedlings and saplings apiece, the average for all being 263.

A careful description is made of the location of each plot to insure its ready revisitation when desired. The altitude, slope, character of the soil, moisture conditions, ground cover (especially forage species) and density and condition of the reproduction are recorded.

As a basis of comparison for future studies each conifer seedling or sapling not over 5½ feet high[1] occurring within the sample plots is carefully listed according to the following outline:

A. *Height:*
- (*a*) Below 6 inches.
- (*b*) 6 inches to 1½ feet.
- (*c*) 1½ to 2½ feet.
- (*d*) 2½ to 3½ feet.
- (*e*) 3½ to 4½ feet.
- (*f*) 4½ to 5½ feet.

B. *Species:*
- This is noted by initials, as Y. P. for yellow pine, D. F. for Douglas fir, etc.

C. *Condition:*
- (*a*) Killed by grazing.
- (*b*) Not grazed nor trampled by stock.
- (*c*) Grazed or trampled by stock, but not killed.
  - (1) Year when injury was inflicted, e. g., 1908, 1909, 1910 or 1911.
  - (2) Character of injury.
    - *a*. Leader removed.
    - *b*. Lateral shoots browsed, without removal of leader.
    - *c*. Injury confined to removal of needles.
    - *d*. Injury inflicted by trampling.

METHOD OF RECORDING.

A special form for recording the data—Form 770, "Record of Injury by Grazing"—has been printed. On it provision is made for recording the reproduction killed, grazed but not killed, trampled and ungrazed; the year in which the last most serious injury was inflicted; the kind of injury done, and the height of each sapling examined. The dot-and-line system of tallying, described on page 77 of the Woodsman's Handbook, Forest Service Bulletin 36, is used. Symbols are employed to represent four kinds of grazing injury and also to denote a browsing injury the year of which can not be definitely determined.

The obverse and reverse sides of Form 770, which is 8 by 10½ inches in size, are shown on p. 20.

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[1] When a coniferous sapling is 5½ feet high it is practically immune from serious lesions inflicted by stock.

[Obverse.]

Form 770. Plot No._____

UNITED STATES DEPARTMENT OF AGRICULTURE.
FOREST SERVICE.

RECORD OF INJURY BY GRAZING.

Height.	Species.	Killed.	Grazed. 19	19	19	19	Ungrazed.
Below 6 inches.							
6 inches to 1½ feet.							
1½ to 2½ feet.							
2½ to 3½ feet.							
3½ to 4½ feet.							
4½ to 5½ feet.							

LEGEND.

● Removal of leader.
× Browse without removal of leader.
○ Injury only to extent of removal of needles.
⊖ Browse year indefinite (to be noted in fourth injured column).
\+ Injured by trampling.

[Reverse.]

Date of count..... .....National Forest.
Size of plot.....
Location of plot.....

Altitude.....
Slope and aspect.....
Ground cover.....

Soil.....
Forest type.....
Reproduction (density, condition, etc.).....
Remarks: .....

PHOTOGRAPHIC DATA.

The importance of the camera as an adjunct in a study of this kind can scarcely be overemphasized. By photographing year after year seedlings and saplings which exhibit various kinds of grazing injuries a very valuable series of pictures will eventually be obtained, making it possible to note the recovery ocularly. In collecting these data the following procedure is closely adhered to:

SELECTION AND PERMANENT MARKING OF THE SPECIMEN.

The specimen is selected with a view to its representation of some typical injury, as loss of terminal shoot, removal of bark near base by trampling or rubbing, and so on. It is then tagged with a numbered aluminum label fastened by wire around one of the branches in such a way as to avoid girdling or other injury, and its position in the fenced area is exactly noted.

DESCRIPTION OF THE SPECIMEN.

A rough sketch of the plant is prepared to accompany the description and the photograph, and notes are made of the following points: Species, height, number of side shoots and their relative position, character of injury or injuries, vigor and apparent chances of recovery.

PHOTOGRAPHIC DETAILS.

Notes were made of the following points: Light intensity, kind of photographic plate used, exposure, aperture, direction of object from lens, distance of object from lens, size of photograph as compared with plant.

A stake is driven into the ground directly beneath the lens to insure rephotographing from the same position, and, whenever convenient, a measuring stick is placed upright beside the plant. If possible the same camera, lens, and kind of plate will be used in rephotographing the specimen.

RESULTS.

The plots contained, at the time the third count (June–July, 1912) was made, 10,885 living seedlings and saplings under 5 feet 6 inches in height. In this number were represented all the five economically important species, their numerical ratio, sugar pine represented as 1.00, being white fir, 3.98; Douglas fir, 6.82; yellow pine, 17.96; incense cedar, 20.88.

The three counts, taken at the beginning of the grazing season of 1911 and at its close, and at the beginning of the 1912 grazing season, respectively, show the same general tendencies. The third count

represents the largest number of plots, and, on that account may be considered the most accurate. A synopsis of it is given below.

Count of seedlings and saplings under 5 feet 6 inches in height.

YELLOW PINE.*

Kind of range.	Grazed.		Ungrazed.		Trampled.		Killed.		Total.
	No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*	
Cattle	85	8.09	931	88.58	35	3.33	0	0	1,051
Sheep	746	38.24	1,165	59.71	40	2.05	0	0	1,951
Goat	427	49.71	424	49.36	7	0.81	1	0.12	859
Total or average	1,258	32.58	2,520	65.27	82	2.12	1	0.03	3,861

INCENSE CEDAR.

Cattle	0	0	1,260	99.45	7	0.55	0	0	1,267
Sheep	0	0	502	93.83	33	6.17	0	0	535
Goat	[1] 57	2.12	2,626	97.69	5	0.19	0	0	2,688
Total or average	[1] 57	1.27	4,388	97.73	45	1.00	0	0	4,490

DOUGLAS FIR.

Cattle	106	18.93	441	78.75	12	2.14	1	0.18	560
Sheep	107	21.75	381	77.44	4	0.81	0	0	492
Goat	54	13.01	359	86.51	2	0.48	0	0	415
Total or average	267	18.20	1,181	80.50	18	1.23	1	0.07	1,467

WHITE FIR.

Cattle	[2] 35	10.97	280	87.78	4	1.25	0	0	319
Sheep	29	48.33	29	48.33	2	3.33	0	0	60
Goat	111	23.32	358	75.21	[3] 6	1.26	1	0.21	476
Total or average	175	20.47	667	78.01	12	1.40	1	0.12	855

SUGAR PINE.

Cattle	10	12.50	69	86.25	1	1.25	0	0	80
Sheep	14	26.92	36	69.23	2	3.85	0	0	52
Goat	41	49.40	41	49.40	1	1.20	0	0	83
Total or average	65	30.23	146	67.91	4	1.86	0	0	215

GRAND TOTAL.

Cattle	236	7.20	2,981	90.97	59	1.80	1	0.03	3,277
Sheep	896	29.00	2,113	68.38	81	2.62	0	0	3,090
Goat	690	15.26	3,808	84.23	21	0.47	2	0.04	4,521
Total or average	1,822	16.73	8,902	81.76	161	1.48	3	0.03	10,888

[1] The infliction of 4 of these by goats is questionable.
[2] 2 of these are questionable as due to stock.
[3] 1 of these is dying.

* Of the 746 "grazed" on the sheep range porcupines, squirrels, fungi, and mistletoe should perhaps be held responsible in part on 2 of the plots. Of the 85 "grazed" on the cattle range 5 are questionable. Of the 427 "grazed" on the goat range 1 is questionable. Of the 35 "trampled" on the cattle range 1 was perhaps injured by a landslide instead.

Besides the 10,885 living seedlings and saplings there were 155 dead specimens of young forest growth in the sample plots, making a total

of 11,040 seedlings and saplings examined. The causes for the deaths of these 155 young trees are shown below:

Under 6 inches in height, dead from drought and damping off	111
Under 6 inches in height, dead as a result of injuries from setting posts around fenced area	2
Between 6 inches and 5½ feet, dead from pathological conditions	20
Between 6 inches and 1½ feet, dead from drought	12
Douglas fir, between 6 inches and 1½ feet, dead probably from drought	1
Yellow pine, between 6 inches and 1½ feet, dead probably from drought	1
Yellow pines, between 6 inches and 1½ feet, girdled apparently by a landslide	2
Yellow pines, between 6 inches and 1½ feet, killed by gophers	2
Douglas fir, between 6 inches and 1½ feet, practically dead; girdled by gophers in 1911	1
Killed by agencies other than stock	152

The three saplings killed by stock were as follows:

1. A white fir, on goat range, between 6 inches and 1½ feet, killed by severe browsing.
2. A yellow pine, on goat range, between 2½ and 3½ feet, killed by peeling off bark.
3. A Douglas fir, on cattle range, between 2½ and 3½ feet, almost completely broken off 1 foot above ground.

Thus, of the 155 dead, only 3, or 1.94 per cent, were killed by stock, and out of the 11,040 seedlings and saplings examined, those killed by stock amounted to but 0.027 per cent. It is clear from the figures given that drought, fungi, and rodents (including gophers, squirrels, and porcupines) are responsible for many fatalities among young forest growth.

The preponderance of incense cedar is chiefly due to its astonishingly prolific reproduction. Of the 4,490 incense cedars 5½ feet or less in height included in the sample plots, 3,724, or 82.94 per cent, are under 6 inches in height. In contrast to this is the second most abundant species, yellow pine. Of the 3,861 seedlings and saplings of this species counted, 1,162, or 31.23 per cent, are under 6 inches in height.

The tables indicate that cattle graze Douglas fir more than any of the other species, with sugar pine second, the percentages being 18.92 and 12.50, respectively. The preference for Douglas fir is corroborated by the first two counts and by careful general observations in pastures and near salting grounds and watering places.

The first count showed sugar pine as having the largest grazed percentage on the sheep range, with yellow pine second; the second count gave a like result; the third count, however, would seem to indicate a preference for white fir, with yellow pine and sugar pine second and third. Sheep do not seem to exhibit as clear and certain a preference for one species as do cattle, and further observations will be required to settle definitely the order in which the species are selected. Sheep will not graze incense cedar.

Goats are commonly regarded as paradigms of catholic taste and are the only stock which will eat incense cedar. Nevertheless, they exhibit a very strongly marked preference for the pines. All three

counts indicate that sugar pine and yellow pine are grazed with about equal relish, while the percentages of yellow pine and sugar pine grazed have varied from more than twice to about four times as great as that of their nearest competitor, white fir.

All three counts, for all ranges, show the pines to be the most grazed species, the average for the three being greatest for sugar pine. This preference for sugar pine is especially noticeable in the smaller growth, before it becomes resinous. It is at least partly explained by a chemical analysis made of sugar-pine seedlings, which averaged about a year old, from the Pilgrim Creek Nursery, showing a protein content of 22.51 per cent—about double that of alfalfa hay. An analysis of yellow-pine seedlings made at the same time showed a protein content of 7.29 per cent. Further chemical analyses are being conducted to throw light on the subject of palatability or nonpalatability of the five species.

Sheep appear to do the most trampling injury, the figures being, for all species, 2.62 per cent on sheep range, 1.80 per cent on cattle range, and 0.47 per cent on goat range.

From the table it would also appear that the greatest injury from grazing is found on the sheep range, the percentages grazed being 29, 15.26, and 7.20 on the sheep, goat, and cattle ranges, respectively. However, it should be borne in mind that the 7 plots on the goat range contain over five times as much incense cedar reproduction as the 22 plots on the sheep range, the exact figures being 2,626 as opposed to 502. If this unpalatable species is eliminated from the tabulation, we find the percentage of grazed on the sheep and goat ranges to be 35.07 and 34.53, respectively. Over half of the yellow-pine reproduction counted is found on the sheep range, which is also the center of yellow-pine fungus and mistletoe infection, and, as noted in the table, some of the damage attributed to sheep is perhaps pathological. The worst feature of a grazing injury is often not the injury itself, which may be relatively insignificant, but the fact that the lesion serves as an entrance to fungi, mistletoe, and other parasites.

In reviewing the tables it should be borne in mind that the term "grazed" includes all forms of grazing injury, and that a large portion of these injuries consist merely of removal of a few needles or of some lateral shoot, which, in the great majority of cases, do not seriously retard the development of the sapling. The only cases of what, from the silvicultural standpoint, might be called serious injury have been found on the goat and sheep ranges, and such changes in management as may eventually be required by the findings of this study will be confined in all likelihood to the allotments of those animals. As to just what changes will be required, no definite statement can be made until the study is completed. However, goats on the Shasta National Forest have now been removed from ranges where there is important timber reproduction.

ERADICATION OF CHAPARRAL BY GOAT GRAZING.

LASSEN NATIONAL FOREST.

JOHN H. HATTON, *Assistant District Forester.*

OBJECT.

During the summer of 1908 a band of goats grazed on patented land near the boundary of the Lassen Forest. Their tendency to girdle the manzanita led the forest officers to believe that if goats were confined to brush areas they might kill a large part of the objectionable manzanita as well as other species, and in addition the grazing would help in protection against fire. Accordingly, in April, 1909, an experiment was initiated for the purpose of determining the practicability of using goats in exterminating chaparral where the manzanita makes up a large portion of the brush, the ultimate aim being to prepare the areas for artificial or natural reforestation. Since the Lassen Forest contains about 300,000 acres of chaparral and goats were available there for the test, that Forest was chosen for the experiment.

GENERAL CONDITIONS.

The value of the chaparral type in southern California for watershed protection is unquestioned and every effort is made to protect it. The chaparral fields of northern California, however, are very different. They comprise immense waste areas, many of them showing evidence of having once been forest covered, located high on slopes of level-topped ridges with forest above and, in some cases, many miles from heavy timber below, lying between the chaparral and irrigable lands in the upper Sacramento Valley.

The following table shows the principal species comprising the brush fields in order of their predominance:

Common name.	Scientific name.
1. Manzanita	(*a*) Arctostaphylos glauca.
	(*b*) Arctostaphylos pungens.
	(*c*) Arctostaphylos patula (?).
2. Western service berry	Amelanchier alnifolia.
3. White thorn or buck brush	Ceanothus cordulatus.
4. Snow brush	Ceanothus velutinus.
5. Blue brush	Ceanothus thyrsiflorus.
6. Wild cherry	Prunus emarginata.
7. Chemisal	Adenostoma fasciculatum.
8. Chinquapin	Castenopsis chrysophilla minor.
9. Sage brush	Artemisia tridentata.
10. Azalea	Rhododendron occidentalis.
11. Curl-leaf mahogany	Cercocarpus ledifolius.
12. Birch-leaf mahogany	Cercocarpus parvifolius.

The approximate order of abundance of these species is:

	Per cent.
Manzanita	60
Snow brush	20
White thorn	10
All others	10

The manzanita varies from 2 to 6 feet high, depending upon how recently the area has been burned over.

In addition to hindering the reproduction of valuable tree species, these brush areas are often a hindrance to the administration of the Forests. Traveling is difficult, if not impossible, through them, and in times of fire they are controlled with difficulty, if at all.

Several methods of eradicating the chaparral have been tried experimentally with the ultimate aim of preparing the areas for artificial or natural reforestation. In southern California the brush was grubbed out, and on the Sierra National Forest systematic burning was tried. As far as they have been carried out, both of these studies show indifferent results.

OPERATIONS.

The plan of the experiment was to cut trails through the brush parallel to the contours of the slope at intervals of approximately 80 rods, the trails to be of such width that the goats would follow them.

It was expected that the goats could be made to feed out in either direction from these trails. The estimated time for killing the brush on a given area was five seasons, two years to kill the existing brush and three seasons more to kill the sprouts which might come up. An agreement was entered into between the Forest Service and a breeder of Angora goats which provided for the grazing of 3,000 goats free of charge, provided the owner would furnish the necessary labor for cutting the trails and would handle the goats according to the plan of the experiment.

RESULTS.

The first season was unusually backward. The snow remained until late, and it was impracticable to do any work on the trails until about the middle of June. Two bands of goats of about 1,150 each were put on—one dry, the other does and kids. Contrary to expectations the goats did not concentrate on the brush next to the trails, but grazed mostly down the slopes, the way the brush leaned, entirely across the tract below the trails on which they were started. (Pl. II, fig. 1.) The trails, therefore, did not control the goats, since the brush was not impenetrable. After entering it they would very rarely return to the trail unless herded. They would go on through, stopping to eat what met their particular fancy, and as a usual thing made

steady progress either to camp or where they knew more desirable feed was growing.

The general tendency was to work up the hill in very high brush, but down the hill in low brush. The work the first season, however, was somewhat gratifying. The goats worked surprisingly well on the bark of the manzanita, girdling it. About 60 per cent of the green burs on the chinquapin were eaten. But all the terminal shoots of red fir and yellow pine within reach were taken. The lower branches of the manzanita were very well peeled, although the leaves did not wither until the next season. The snow brush and other species were hardly touched, except upon and in the close vicinity of bedding grounds, where practically everything was killed except white thorn (*Ceanothus cordulatus*).

The kid band was, to a large extent, a failure. The herder, looking for more succulent feed, pushed the band too fast, and did not concentrate it on the brush adjoining the trails. There was a larger percentage of manzanita on the areas grazed.

Some of the good results of the first season, accomplished mostly by the dry band, were: Girdling and killing about 75 per cent of the manzanita where the goats were concentrated, eating 60 per cent of the chinquapin seed, making trails through the brush, and chopping up the ground litter. The harm done consisted in killing or injuring tree seedlings wherever encountered. The goats were taken off some of the trails about the middle of August.

The work of the following season was much less encouraging, and practically failed. Some of the shoots which came on after August 15 attained a length of about 15 inches—a few of them winter killed. The band of dry goats was put on this season June 19 and the kid band June 25. They entered late, as in the preceding season. The goats did not take to the trail and brush work satisfactorily at all for the first week. The brush killed during the first season was hard and stiff, and tore off considerable mohair. The quantity and quality of feed was also much reduced, and it was necessary to graze part of the time on adjacent timbered areas where better forage could be obtained. From the goat owner's standpoint the objections to the system gradually increased. One of the biggest problems was to secure herders who would comply with the contract. The work was hard and they did not take kindly to it. Like most herders, they followed the lines of least resistance and were particular to see that the goats had plenty of good feed. Herders were scarce, too, and would quit if placed under too many restrictions.

The season of 1910 was also an unusually bad fire season, and the local forest officers could not supervise the experiment as closely as in the previous season.

CONCLUSIONS.

There are two features to this experiment. One is based upon its silvicultural aspect and the other upon the economical—the latter viewed from the owner's standpoint. If the two features can not be brought into harmony, the plan must fail. While the work accomplished the first season was fairly gratifying, it only required an additional season to show that it was impracticable if proper consideration was given the goats. The kid band failed because the does had to have more succulent feed than this type of brush afforded. The dry band could not be concentrated properly the second season, and the amount of brush killed was not of enough importance to warrant free grazing or the continuance of the plan.

It is doubtful, too, whether the injury to seedlings hidden through the brush would be compensated for by the benefits in brush extermination. While the results are not absolutely conclusive from a scientific standpoint, the conclusion reached is that the experiment is not practical, although goats, if confined and starved to it, will destroy almost any type of brush. If the Service owned the goats and was concerned only in keeping them in fair condition, and would closely concentrate them by the use of inclosures, good work could be done. The stockman, however, operates for maximum profits, and free grazing, in consideration of the work done on trails, with the restrictions imposed by the kind of contract necessary to accomplish the desired results, is not compensated for by the loss in growth and condition of the goats.

FIG. 1.—GOATS GRAZING IN BRUSH ON THE LASSEN NATIONAL FOREST. GOATS KILL THE BRUSH BY GIRDLING IT.

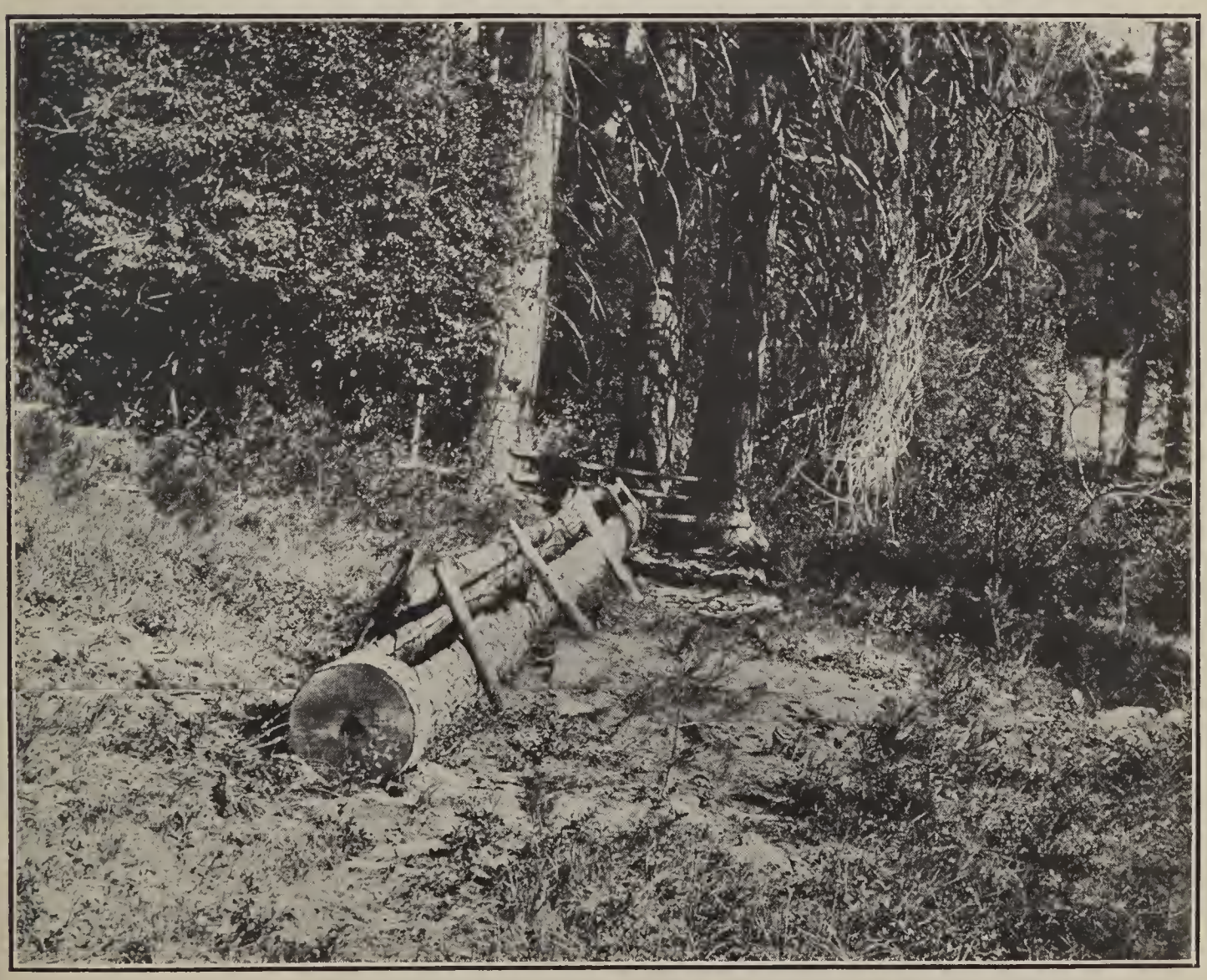

FIG. 2.—VIEW OF WATERING TROUGH FULL OF WATER.

STUDIES IN METHODS OF DEVELOPING STOCK-WATERING PLACES

WATER DEVELOPMENT AT THE COYOTE-PROOF PASTURE.

WALLOWA NATIONAL FOREST.

JAMES T. JARDINE, *Inspector of Grazing.*

OBJECT.

The experimental investigation at the coyote-proof pasture has been a study of the methods of handling sheep, with a view to bringing about a system of management that will result in the most economical utilization of the forage on grazing lands. Whatever system may be adopted, it can not reach the state of efficiency desired unless the range in question is supplied with the necessary watering facilities. The amount of water that sheep need will depend to a considerable extent upon the kind of forage they have, and upon the locality. But the number of watering places necessary and their distribution should be governed by the acreage of a range, its topography, and its acreage-carrying capacity. There are, perhaps, few places where the ideal conditions can be realized, but much can be done, at a comparatively low cost, by developing small springs that are of little or no value in their undeveloped state. The object in view of this study was to devise a system of development that would be applicable, with slight modification, in many mountain sections where it is impracticable to construct lumber or metallic troughs.

LOCATION.

The information contained in this report is based on data collected during the season of 1908 as a result of investigations along this line at the coyote-proof pasture, on the Wallowa National Forest, in Oregon.

OPERATIONS.

WATER DEVELOPMENT.

Before the forage crop on grazing lands can be utilized to the best advantage, it is very necessary that the supply of water be developed sufficiently to insure:

1. The utilization of every portion of a range.
2. Equal distribution of stock.
3. The prevention of forage destruction by herds trailing long distances to water, and remaining in large bunches near the source of supply.
4. Sufficient water to grow the best of beef or mutton with the minimum amount of forage.

In order to approach such a development as nearly as possible in the coyote-proof experimental area, three small springs were developed and troughed before the grazing season opened in 1908.

Spring No. 1 furnishes a mere dribble, but is constant in flow throughout the summer. When unfenced and undeveloped the condition of the spring was such that it was scarcely possible for one animal to get a drink. The entire work of development consisted of:

1. Cleaning out the spring hole.
2. Constructing an intake of about 40 feet.
3. Making 64 feet of troughing with a cubic capacity of 32 feet
4. Placement of troughs and intake.
5. Fencing spring.

In order to secure the small stream of water desired it was necessary only to clean out the spring hole about 6 feet square and make a slight dam to concentrate the outflow. This was the work of one man for three hours.

Intake.—The intake was constructed by making open-gutter troughs out of lodgepole, about 6 inches in diameter. The lodgepole was used because it is more uniform at that size, and hews out more readily than either red fir or tamarack. The troughing, approximately U-shaped, with a cross section of 3 by 3 inches, was hewed out with an ax, at the rate of 30 feet an hour for two men. This kind of intake was used in preference to iron or galvanized pipe, because (*a*) it could be made readily and cheaply on the ground; (*b*) during eight months of the season iron pipe would be in danger of breaking by frost unless the water was drained off; (*c*) silt, moss, and pebbles are more easily cleaned from the open trough. Where the intake extends outside of the inclosure it would be necessary to use closed pipe. It would also be necessary to use closed pipe where the intake is very long.

Troughs.—The entire retaining trough was in four sections, each 14 feet on the inside, with a total capacity of 32 cubic feet for the four. They were hewed from one tamarack tree, approximately 27 inches in diameter at the butt.

The work was done by two men with saw, ax, and foot adz at the rate of $2\frac{1}{2}$ cubic feet water capacity per hour. With labor at $2.50 for eight hours the cost per cubic foot water capacity was .26 cents.

The troughs were placed in one line, end to end, with a very slight fall from each trough to the succeeding one, away from the intake. This insures a constant flow of water through the entire length when full, and keeps the water fresh. Besides, it takes the waste overflow to the far end where it can be carried away through a covered drain. With this arrangement the troughs can all be kept full of fresh water without any overflow to cause mudholes and pools near

by. Each section is provided with a 2-inch sluice hole in the lowest part of the trough in order that the silt from the bottom can be washed out without difficulty.

To keep sheep from jumping over the trough or into it, a small pole was placed above the water surface just high enough to allow a sheep to put its head under from either side and yet prevent a lamb from falling in on its back.

Inclosure.—The spring, intake, and the end of the trough were inclosed by a 6-wire fence in order to keep sheep out.

The total cost, with labor at $2.50 per day, was $20.50.

Plate II, figure 2, gives a view of this trough full of water.

Spring No. 2 furnishes a good flow of water early in season, but gradually dries to a pool with no outflow by August 20 to 30. This was troughed in order to use, economically, the spring range near it.

Partly because tamarack was not handy and partly for the experiment, this set of troughs was made from yellow pine. It was found that the yellow pine does not hew out as easily as tamarack. The cost of making 64 feet of trough, having a water capacity of 32 cubic feet, was $11.25, 35 cents per cubic foot. Aside from this change the method was a duplication of that described for spring No. 1. Total cost, $22, with labor at $2.50 for eight hours.

At spring No. 3 tamarack troughs were used. Sixty-four feet of trough, having a water capacity of 30 cubic feet, was made at a cost of $6.25, 21 cents a cubic-foot capacity. The work of concentrating the water supply and placing the troughs in this case was more difficult than at the other springs, otherwise it was a duplication. Total cost, $26.

It is sometimes contended that log troughs can be made at less cost by burning out the interior than by hewing. In making the troughs above described both methods were tried. The comparative cost of the two methods depends upon several factors:

1. The kind of timber used, and its size.
2. The amount of troughing to be made at any one place or locality.
3. Whether or not a man has other work that he can devote himself to while the burning is going on.

Tamarack for average-sized troughs does not burn well, while it hews comparatively easy. Therefore, it can best be hewed. Yellow pine is difficult to hew out, while it burns out quite readily. Whether it will pay to burn it or not depends upon the amount to be made, and whether or not a man is devoting his entire time to this work alone. If only one trough is to be made, and a man is working at nothing else, he can have it completed by hewing about as soon or sooner than it will burn. After the burning it must be cleaned out and smoothed up.

If the workman can start his fires and then do other work while the trough is being burned, this method, perhaps, is the cheapest. Where one man has a great amount of troughing to make in one locality he can burn it out to advantage. In such a case the first one is burned out by the time the last one is started. He can then go to work cleaning and shaping without losing time. Ordinarily it is more economical to hew, providing the workman can handle an ax and adz.

At the pasture springs it was estimated that only a few hundred sheep would go to the trough at any one time. In such instance 64 feet of troughing, having a cubic capacity of 32 feet, is sufficient. If the entire band of 2,500 or 3,000 head must water at a trough in a short time it would be necessary to have in the neighborhood of 100 feet of trough with an available water supply of perhaps 75 cubic feet or more. Much will depend of course on the frequency of watering, the size of the band, the weather, and the length of time that the band is near the trough. Unless the system is adequate, the leaders of the band will drink and trail away. Many of the others, much to their disadvantage, will follow up before they have watered.

PRODUCTS INVESTIGATIONS.

STUDIES IN MECHANICAL PROPERTIES.

A MICROSCOPIC STUDY OF THE MECHANICAL FAILURE OF WOOD.

WARREN D. BRUSH, *Expert.*

OBJECT OF STUDY.

The object of this microscopic study was to determine the exact behavior of the individual fibers when wood is subjected to mechanical stress. Wood is composed of several classes of minute cellular units which, in different species, differ greatly not only in form and size, but also in relative abundance and in distribution. Also, in different species the same classes of cells differ in size and in the thickness of their walls, and in trees of the same species there are characteristic differences, due to variations in growth during different seasons of the year and at different periods in the life of the tree. This variation in the structure of wood is associated with variation in its mechanical behavior, and discovery of the interrelation of the two is a problem which must be solved before the knowledge of the mechanical properties of wood is complete.

The study is a part of the general problem of the correlation of the microscopic structure of wood with its physical and mechanical properties, which the Forest Service is investigating.

STRUCTURE OF WOOD.[1]

Wood is composed of minute hollow tubes or cells. (Figs. 1 and 2, Pl. III.) The majority of these elements (commonly called fibers) are elongated in form, tapered at the ends, and extend longitudinally in the trees. In the wood of coniferous or needle-leafed trees these fibers (called tracheids) are all of the same kind and approximately of the same size. The fibers formed in the early part of the growing season are thinner walled than those formed later in the year. The latter are not only thicker walled, but also smaller in radial diameter. This difference is especially marked in the hard pines. In the soft pines the difference between the fibers in early and late wood is not so great, hence there is greater uniformity in the structure of the wood.

[1] For a more detailed description of wood structure see Forest Service Bulletins 10, 13, 101, 102, and 103 and Circulars 184 and 185.

Running at right angles to the tracheids and in a radial direction, i. e., from the pith to the bark in the tree, are narrow blade-like structures called pith rays (Pl. III, fig. 2 p. r.), composed of brick-shaped thin walled cells.

In the wood of broadleafed trees, the so-called hardwoods, the structure differs in several important features from that of the conifers. There are several different kinds of cells running longitudinally, the main body of which (the wood fibers, properly so called) are smaller in diameter and have thicker walls than the tracheids of coniferous woods, so that the cell cavity is often almost obliterated. Hardwoods differ further from conifers in having vessels or pores. These are of comparatively large diameter and form continuous longitudinal channels through the wood. In many species the pores are confined almost entirely to the early wood.

Still other cells of the hardwoods are known as tracheids and wood-parenchyma cells. These and the vessels are much thinner walled than the wood fibers and have a very limited mechanical function. Very broad pith rays occur in some species of broadleafed trees in addition to narrow ones similar to those found in conifers. In many coniferous woods, especially the pines and spruces, longitudinal openings or channels called resin ducts occur between the cells; these appear to the naked eye as dots on a transversely cut surface.

MATERIAL AND METHODS OF STUDY.

Blocks of wood for this study were stressed in a testing machine in the manner commonly used by the Forest Service in making mechanical tests.[1] The blocks were loaded until failure occurred, and thin sections for microscopic examination were cut from the place of failure. More than a thousand sections, including 10 species of woods, were examined. The species studied are white pine (*Pinus strobus*), red spruce (*Picea rubens*), Douglas fir (*Pseudotsuga taxifolia*), longleaf pine (*Pinus palustris*), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), hemlock (*Tsuga canadensis*), white oak (*Quercus alba*), chestnut (*Castanea dentata*), and tulip (*Liriodendron tulipifera*). In almost every case two or more blocks of each species which had been ruptured in the air-dry condition were examined, and comparison was made also of blocks which had been ruptured under different moisture conditions. The observations made on each section were carefully compared in order to summarize the results of the study, and in some cases sketches were made direct from the microscope with the aid of the camera lucida for comparison and illustration of the different kinds of cell failure.

[1] The method of making these tests is described in Forest Service Circular 38, "Instructions to Engineers of Timber Tests," revised.

HOW THE FIBERS OF THE WOOD FAIL UNDER STRESS.

When a block of wood is subjected to stress until failure takes place, every fiber of a given size and thickness of wall fails in the same characteristic manner under the same conditions of stress. This was found to be true of all the woods studied irrespective of species or arrangement of the fibers. The manner of failure of the fibers will be described separately under each method of stress.

COMPRESSION PARALLEL WITH THE FIBERS.

This kind of stress, called also end compression, occurs when a load is applied to the end of a block of wood in a direction parallel with the fibers. The specimens examined were loaded until a well-defined rupture or break in the wood took place. An examination of sections of the wood taken at the place of failure shows that the fibers, which act as hollow tubes bound closely together, either buckle, the fiber wall bending sharply, and often doubling upon itself, or the fibers bend without buckling in more or less regular curves. (Pl. III, figs. 3 and 4, and Pl. IV, figs. 1 and 2.) This buckling was found to take place in the fiber walls of all the species investigated. Whether the fiber buckles or bends without buckling depends upon the thickness of the wall and on the moisture content.

LONGITUDINAL SHEAR.

Failure under this kind of stress occurs when a load is applied to an unsupported portion of a block of wood in the direction parallel with the fibers, so that the part under load is made to slide upon or is forced away from the unloaded and supported portion. The failure takes place either through a longitudinal break in the fiber wall along the entire length of the fiber, or the individual fibers separate from each other. (Pl. III, fig. 5, and Pl. IV, figs. 3 and 4.) Here, as in end compression, the manner of failure is dependent upon thickness of the fiber wall and the moisture condition.

TENSION.

When a stick of wood is torn apart by a pulling force acting in a direction parallel with the fibers the wood is said to fail in tension. In this case the fibers are broken crosswise; no separation of the fibers along the fiber walls takes place. This is true of both thick and thin wall fibers. Moisture conditions, likewise, have no influence on tension failure. Figure 6 of Plate III shows the broken edge of a block of wood of white pine which has failed in tension parallel with the fibers. The fiber walls are torn across obliquely and usually in a spiral direction.

COMPRESSION ACROSS THE FIBERS.

When pressure is applied to a block of wood in a direction at right angles to the fibers, so that the block is crushed, it is said to fail by

compression perpendicular to or at right angles to the fibers. An examination of the cells in cross section shows that the fiber walls in this case are merely pressed together, more or less closing the cell cavities. As is the case in tension failure, thickness of cell wall and moisture condition have no influence on the behavior of the cells.

BENDING.

In the case of a beam supported at both ends and loaded in the middle the stresses are quite complex. Longitudinal compression takes place in the upper portion of the beam, tension in the lower portion, and longitudinal shearing stresses are developed to more or less extent throughout the beam. Consequently the failure which results may be either a tension, compression, or shear failure, or a combination of two or of all of these. Taken separately, these failures are not different from those produced by each of the forces acting independently.

RELATION OF THICKNESS OF FIBER WALLS TO MANNER OF FAILURE.

COMPRESSION PARALLEL WITH THE FIBERS.

Figure 1 of Plate IV shows an end compression failure of the thin-walled fibers of red spruce in the air-dry condition. The fiber walls are bent sharply and irregularly, and in places the wall is folded over on itself as at (X) in the figure. Figure 4 of Plate III is a drawing of a single fiber of red spruce showing this kind of failure. The failure has here only begun, and the wall has "crinkled" across in an oblique direction. This is the usual failure in fibers of dry wood of red spruce which results from end compression, except that the fibers of the late wood, which make up the last few rows in each annual ring, and are thicker walled, form a more gradual curve in failure.

Figure 3 of Plate III is a single fiber of air-dry wood of white pine which failed in end compression. The cell walls have curved sharply, as was the case in red spruce. White pine is made up almost entirely of thin-walled cells, and this is the common manner of failure of the fibers of dry wood of this species. This sharp bending or buckling of the fiber walls was found to take place in the early wood (thin-walled cells) of all the hard pines studied—longleaf, shortleaf, and loblolly—and of hemlock and Douglas fir a well. In the last-named wood the fiber walls are not bent so sharply as in the other species studied, which is due to their spiral thickenings. In the three broad-leafed species studied, viz, white oak, chestnut, and tulip, this sharp bending or buckling of the fiber walls in failure occurs only in the extremely thin-walled elements of the wood, viz, vessels, tracheids, and wood-parenchyma cells; these, as has been stated, have a very limited mechanical function.

The manner of failure of the thick-walled cells of the species studied is somewhat different from that in the thin-walled cells. In

Fig: 1.

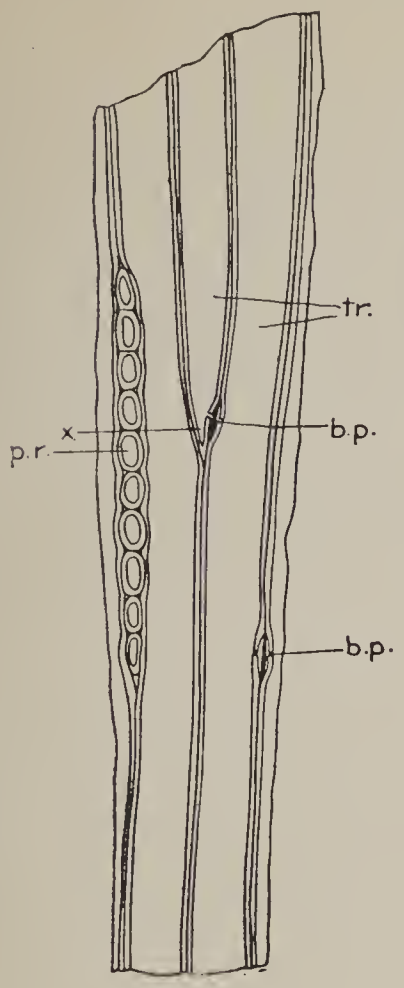

Fig. 2.

Fig. 3.

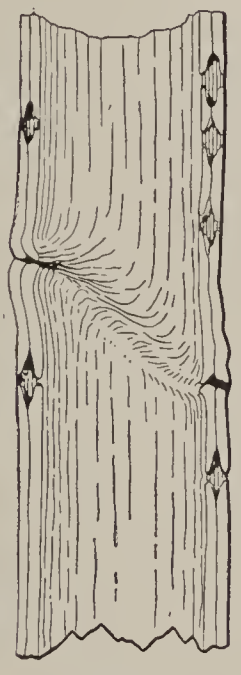

Fig. 4.

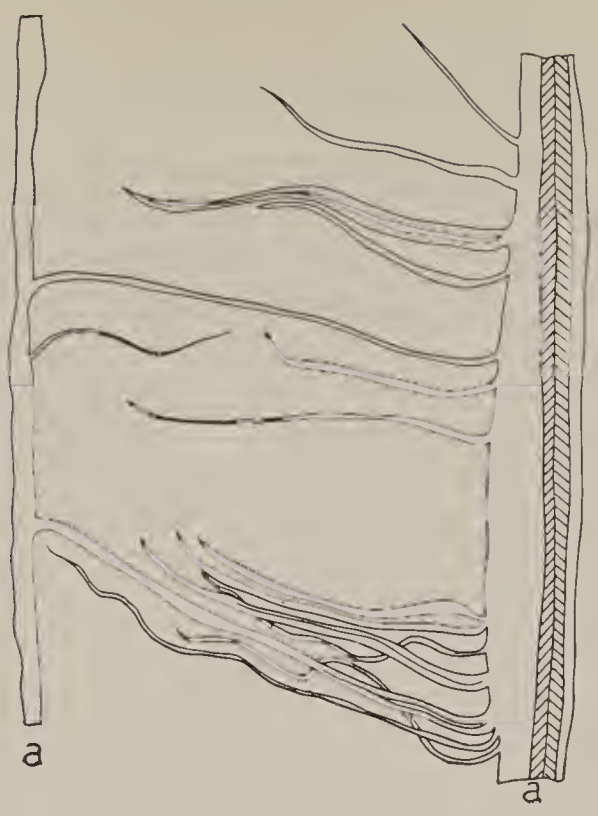

Fig. 5.

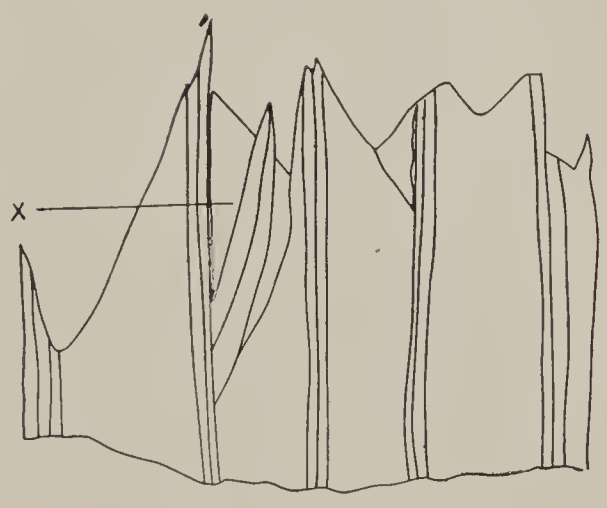

Fig. 6.

Fig. 7.

MICROSCOPIC STRUCTURE OF WOOD.

Fig. 1. A fiber (tracheid) from the wood of red spruce. b. p., bordered pits. Magnified about 40 diameters.

Fig. 2. Sketch of a tangential section of the wood of white pine showing longitudinal fibers (tracheids, tr.) and pith ray (p. r.) cut transversely. b. p., bordered pit. x, end of a fiber. Magnified about 150 diameters.

Fig. 3. Sketch of a portion of a fiber (tracheid) of white pine showing manner of failure in dry wood under compression parallel with fibers. The failure is here complete. Magnified about 200 diameters.

Fig. 4. Sketch of tangential section of a fiber (tracheid) of red spruce showing the beginning of failure in dry wood under compression parallel with the fibers. Magnified about 500 diameters. Forest Service Bulletin 70.

Fig. 5. Sketch of a portion of a fiber (tracheid) of white pine showing manner of failure in dry wood in shear parallel with the fibers. The walls of the fiber (a. a.) are still connected by shreds. Magnified about 200 diameters.

Fig. 6. Sketch of a tangential section of white-pine wood which failed in tension parallel with fibers. Fibers are torn across usually in a spiral direction as shown at x. Magnified about 200 diameters.

Fig. 7. Sketch of a portion of a fiber of white pine showing manner of failure in green or moist wood under compression parallel with fibers. m. r.=pith ray. Magnified about 200 diameters.

Fig. 1.

Fig. 2.

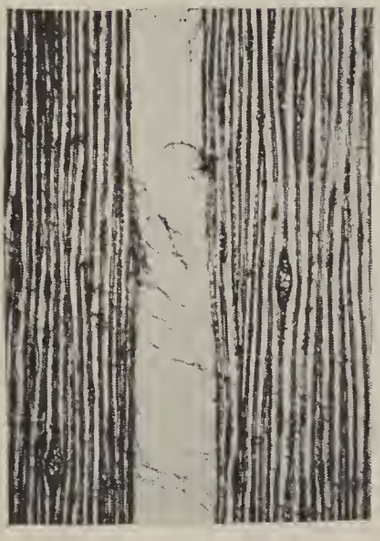

Fig. 3.

Fig. 4.

Fig. 5.

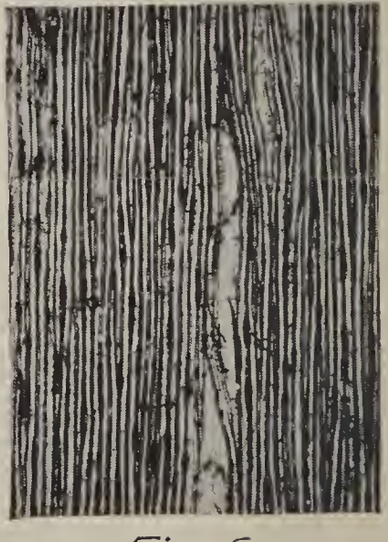

Fig. 6.

MICROSCOPIC STRUCTURE OF WOOD.

Fig. 1. Tangential section of dry wood of red spruce which failed in compression parallel with fibers. Magnified 100 diameters.

Fig. 2. Tangential section of dry wood of longleaf pine which failed in compression parallel with fibers. Magnified 20 diameters.

Fig. 3. Tangential section of dry early wood of white pine which failed in shear parallel with fibers. Shreds of torn fiber wall visible in middle of section similar to those shown in plate. Magnified 20 diameters.

Fig. 4. Tangential section of dry late wood of red spruce which failed in shear parallel with fibers. A single fiber visible connecting the two parts of the wood sheared apart. Magnified 20 diameters.

Fig. 5. Tangential section of green late wood of longleaf pine which failed in compression parallel with fibers. Magnified 20 diameters.

Fig. 6. Tangential section of green early wood of white pine which failed in shear parallel with fibers. Magnified 20 diameters.

the former case the walls are not bent so sharply, as shown by the comparatively regular curves in Plate IV, figure 2, which illustrates a typical failure of the late wood in air-dry longleaf pine. Also some slight separation of cells usually takes place where the fiber walls are thick, especially where medullary rays separate the fibers. Since white pine, red spruce, hemlock, and Douglas fir have relatively small amounts of late wood, this kind of failure does not occur to any great extent in these woods. It is seen best in the hard pines, where the thick-walled late-wood fibers form very regular curves, and the region of failure has distinct limits, as shown in Plate IV, figure 2. In woods in which the fiber walls show all gradations in thickness between the thin-walled cells of the early wood and the thick-walled cells of the late wood these two kinds of buckling grade into each other. This is true especially of red spruce, but occurs also to a greater or less degree in the other coniferous woods studied, excepting in the three hard pines, where the transition from thin-walled early-wood fibers to thick-walled late-wood fibers is abrupt. In the three broadleafed woods studied the fiber walls are all relatively thick, and the failure characteristic of thick-walled cells occurs.

LONGITUDINAL SHEAR.

In longitudinal shear failure also the thin-walled and thick-walled fibers of the wood behave quite differently. The thin-walled fibers in air-dry wood are torn lengthwise, leaving long narrow strips or irregular shreds along the edge of the break, as shown in Plate III, figure 5, and Plate IV, figure 3. The break usually follows an individual cell for the greater part of its length. This is the characteristic manner of longitudinal shear failure in white pine, and in the thin-walled early-wood fibers of red spruce, hemlock, Douglas fir, as well as in the early wood of longleaf, shortleaf, and loblolly pine, and in the very thin-walled vessels, tracheids and parenchyma cells of white oak, chestnut, and tulip. Where the fibers are thick-walled longitudinal shear failure takes place by separation of the fibers from one another. Figure 4 of Plate IV, which shows a single fiber still connecting the two parts of the block separated in shear, illustrates this manner of failure. It occurs most characteristically in the late wood of the hard pines. This separation of the fibers takes place also in the late wood of the other coniferous woods studied, viz, hemlock, white pine, and Douglas fir, and in the wood fibers of white oak, chestnut, and tulip.

EFFECT OF MOISTURE CONTENT ON FAILURE.

COMPRESSION PARALLEL WITH THE FIBERS.

As the moisture content of the wood is increased the fiber walls describe a more gradual curve in failing. Thus the thin-walled fibers

of the green wood of white pine do not fold over or bend so sharply as in air-dry wood. Figure 7 of Plate III shows the characteristic manner of failure of thin-walled fibers in moist or green wood. The higher the moisture content the larger is the region of failure. This is due to decreased stiffness of the fiber walls with increase of moisture. The same general effect occurs in thick-walled fibers. The curve which the fiber walls describe in the region of failure is more gradual and more irregular in moist or green wood than in dry, and the limits of the region of failure are not as well marked in the former. The fibers also separate from one another in green wood more than in dry; this is true especially of thick-walled fibers, but was observed to some extent with thin-walled fibers also. Figure 5 of Plate IV shows the manner of failure in green late wood of longleaf pine. This is the characteristic failure of thick-walled fibers of wood with a high moisture content.

LONGITUDINAL SHEAR.

A high moisture content results in a greater proportion of the fibers separating from each other in shear failure. This is particularly noticeable in the thin-walled fibers. The fibers are also often broken across irregularly when the moisture content is high. Figure 6 of Plate IV shows this failure in the thin-walled cells of white pine. The two parts of the block which have separated from each other are still held together by groups, and portions of fibers and the fibers have largely separated. With thick-walled fibers the moisture content does not affect the manner of failure so greatly. The thick-walled fibers of the wood separate in shear failure with either a low or high moisture content, but in the latter case the fibers are broken across to a greater extent then when the moisture content is low.

STUDIES IN PHYSICAL PROPERTIES.

WOOD FUEL TESTS.

H. S. Betts, *Engineer in Forest Products.*

OBJECT.

The object of the investigation is to determine the heating values of the woods commonly used for fuel in New Mexico and Arizona, including about 10 different species.

OPERATIONS.

Samples of these woods were tested by burning a small amount of each in a bomb calorimeter, a vessel surrounded by water in such a way that the heat given out by the wood is taken up by the water. The wood was ignited by an electric spark. The rise in temperature of the water gives a measure of the heating value of the wood under test, since different species of wood will raise the temperature of the water different amounts, depending on their fuel value. Separate samples were taken in most cases of heartwood, sapwood, and bark. Samples were also taken, which included heartwood, sapwood, and bark, by boring several holes from the circumference to the center at different places and mixing the different borings, so that a sample representative of the whole piece was obtained.

RESULTS.

The heating values [1] for the different parts of the tree and the corresponding percentages of ash for the species included in the tests are given in Table 1. The heating values for these species are also given in terms of the corresponding values of two kinds of coal commonly used in New Mexico and Arizona and of Bakersfield crude oil.

The wood of alligator juniper and one-seed juniper gave a maximum of heat with a minimum of ash when compared to the other woods tested.

White oak, black oak, and mesquite have less heating capacity than all others tested, and the first two in particular give more ash.

In Douglas fir and yellow pine the bark has a higher heating value than the other parts of the tree, while in alligator juniper and white oak the reverse is the case.

[1] The heating values are given in terms of the British thermal unit—the quantity of heat required to raise the temperature of a pound of water 1° F. at or near its maximum density (39.1° F.).

TABLE 1.—*Heating values of woods used for fuel in New Mexico and Arizona.*

Species.	Part of tree.	Sample.	Ash.	British thermal units per pound oven-dry.	Heating value of wood compared to coal and oil.		
					Dawson coal.	Cerillos anthracite coal.	Bakersfield crude oil.
			Per ct.				
Alligator juniper (Juniperus pachyphlœa).	Butt cut..	Average.....	0.67	10,015	0.81	0.76	0.52
	.....do	Bark.....	10.04	7,367	.59	.56	.38
	Top cut...	Average.....	.55	9,769	.79	.74	.51
One-seed juniper (Juniperus monosperma).	Butt cut..	.....do.....	.20	9,900	.80	.75	.52
	Top cut...	.....do.....	.81	9,518	.77	.72	.50
White fir (Abies concolor).....	Butt cut..	.....do.....	.49	8,912	.72	.67	.46
	Top cut...	.....do.....	.71	8,818	.71	.66	.46
Piñon (Pinus edulis).....	Butt cut..	.....do.....	1.06	8,629	.69	.65	.45
	Top cut...	.....do.....	1.47	8,795	.71	.66	.46
Douglas fir (Pseudotsuga taxifolia)..	Butt cut..	Sapwood....	.12	8,771	.71	.66	.46
	.....do	Bark.....	.95	10,820	.87	.82	.56
	Top cut...	Average.....	.31	8,847	.71	.67	.46
	.....do.....	Knots.....	1.01	9,040	.73	.68	.47
Western yellow pine (Pinus ponderosa).	Butt cut..	Sapwood....	.57	8,856	.71	.67	.46
	.....do	Bark.....	1.30	9,275	.75	.70	.48
Mesquite (Prosopis juliflora).....	.....do	Average.....	3.06	8,330	.67	.63	.43
	Root.....	.....do.....	2.34	8,572	.69	.65	.45
Arizona white oak (Quercus arizonica).	Butt cut..	.....do.....	7.36	7,499	.60	.57	.39
	.....do	Heartwood..	3.70	8,239	.66	.62	.43
	.....do	Sapwood....	5.53	7,620	.61	.57	.40
	.....do	Bark.....	17.38	5,618	.45	.42	.29
	Top cut...	Average.....	3.09	8,244	.66	.62	.43
	.....do	Knots.....	4.11	8,154	.66	.61	.42
Black oak (Quercus emoryi).....	Butt cut..	Average.....	3.70	8,339	.67	.63	.43
	.....do	Heartwood..	12.47	7,497	.60	.56	.39
	.....do	Sapwood....	2.54	8,203	.66	.62	.43
	.....do	Bark.....	9.13	7,839	.63	.59	.41
	Top cut...	Average.....	4.65	8,080	.65	.61	.42
Aspen (Populus tremuloides).....	1-inch board.	.....do.....	.67	8,555	.69	.84	.45

It is interesting to note that the roots of mesquite are capable of producing more heat than the average butt cut.

In the southern part of Arizona, where there is little utilization of timber except for fuel, a strong prejudice exists against the use of certain woods for this purpose. Arizona white oak is held to be a very inferior fuel wood as compared to black oak. While the results of the tests show that white oak has a lower fuel value than black oak, they also show that when the two woods are in the same condition of dryness the difference in their fuel value does not warrant so strong a prejudice against white oak as at present exists. The heating value of an average sample, including sapwood, heartwood, and bark, taken from a butt cut, is about 10 per cent greater in black oak than in white oak. The greatest difference in heating value in the two oaks occurs in the bark, that of black oak being about 28 per cent higher than that of white oak. The ash from an average butt-cut sample was about twice as much in white oak as in black oak.

It should be understood that the values given in Table 1 are for dry wood, and on this account the table will not serve for a comparison of woods under different moisture conditions.

In the case of complete combustion in woods at the same moisture content the figures in the table will approximate very well their rel-

ative heating values. The various conditions under which the wood is burned should be taken into consideration in arriving at actual heating values.

The amount of heat which escapes up the chimney with different conditions of draft varies greatly and so does the dampness of the wood used. Carbon often escapes unconsumed in the form of smoke. Pine, although capable of yielding more heat than oak, may in practice yield less, the smoke of oak being almost entirely consumed, while in pine the carbon and hydrogen may escape in the smoke. Softwoods give a quicker fire than hardwoods. The latter give a more lasting fire, or by burning equal weights a more intense heat is produced with the former. Thoroughly lignified tissue has the same heating value for all species of trees, but the varying forms of tissue found in the different species, the addition of resin and other materials, and the water present in varying amounts cause different woods to have different heating values. All these factors should be taken into consideration in the application of the table.

CONCLUSIONS.

On account of the many factors influencing the solid contents in a cord of wood, and because of the meager information at hand regarding the weights of the woods under test, it was deemed inadvisable to attempt a comparison of the heating values of wood per cord and of coal per ton.

The length, diameter, smoothness, straightness, and method of piling the sticks all have a very telling effect on the solid contents of a cord of wood.

Table 2[1] shows the volume of solid wood per 128 cubic feet of space for sticks of various diameters and lengths.

TABLE 2.—*Volume of solid wood per cord.*

Length of sticks.	Small diameter.		
	Over 5.5 inches.	2.5–5.5 inches.	1–2.5 inches.
	Cu. ft.	*Cu. ft.*	*Cu. ft.*
2 feet	91	84	65
4 feet	89	82	64
8 feet	84	77	59
12 feet	78	71	54

By the use of the figures in Table 2, taken in connection with the weight per cubic foot of the wood under consideration and its moisture condition, a figure for the weight of a cord of the wood can be obtained.

[1] Table 2 was condensed from a larger table in Forest Mensuration, by H. S. Graves.

The following is a formula for determining what the price of wood should be to make it as economical as coal:

Let a=cost of coal per ton or oil per barrel.
Let b=heating value of wood as compared to that of coal or oil.
Let c=cost of wood per cord.
Let x=pounds of wood per cord.

For coal:

$$c=\frac{abx}{2{,}000}$$ [1]

For oil:

$$c=\frac{abx}{338}$$ [2]

This formula is based on the heat the fuel is capable of producing and does not take into account the difference in the cost of handling the various fuels.

As an example, suppose it is desired to find what price can be paid for dry white-oak wood, composed of limbs, in order to make it as economical as Dawson coal. Assume that coal costs $6 per ton and that a cord of the wood under consideration weighs 2,500 pounds.

Table 1 shows the equivalent of white oak in terms of Dawson coal to be 0.66. Then from the formula $c=\frac{6\times0.66\times2{,}500}{2{,}000}=\$4.95$ per cord as the price of the dry wood in order to make it as economical to use as Dawson coal.

In this example the wood is considered as being perfectly dry. Take a second example, where the wood contains 20 per cent of water, a probable condition in actual practice. When wood containing water is burned, part of the heat the wood is capable of yielding is taken up in raising the water to the boiling point and converting it into steam. So the greater the amount of water present the more the heat available for other purposes is cut down. To raise a pound of water from the temperature of the air, say 70° F., to 212° F.—that is, 142°—will require 142 heat units, and to convert this into steam will take 965 [3] heat units more, making a total of 1,107 for each pound of water.

In the second example, since the wood contains 20 per cent of water, for each pound of wood there will be one-fifth pound of water, or the heating efficiency of the dry wood will be cut down by 221.4 heat units ($\frac{1}{5}\times1{,}107$ [4]). This will make the value of the wood compared to Dawson coal 0.64 instead of 0.66. Substituting the new values in the formula $c=\frac{6\times0.64\times2{,}500}{2{,}000}=\$4.80$ per cord as the price of the wood containing 20 per cent of water in order to make it as economical to use as Dawson coal.

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[1] Weight of ton of coal, in pounds.
[2] Weight of barrel of oil, in pounds.
[3] Latent heat of steam.
[4] The heat required to raise the steam to the temperature of the flue gases is not taken into account.

STUDIES IN WOOD DISTILLATION.

THE MARKETS FOR THE PRODUCTS OF THE HARDWOOD DISTILLATION INDUSTRY.[1]

R. C. Palmer, *Assistant Chemical Engineer in Forest Products.*

OBJECT OF INVESTIGATION.

No definite information has ever been available concerning the industries which use the products of the distillation of wood or the proportion of the products that find a market with the various consuming industries. It was felt therefore that if such information could be obtained from the producing plants it might lead to: (1) New markets for the standard products, charcoal, acetate of lime, and wood alcohol; and (2) markets for by-products now being wasted.

All the wood-distillation plants known to be operating were requested to furnish the following information:

1. The quantity of standard or other products produced annually.
2. The average selling price at the plant.
3. The industries that use the products and the proportion going to each.

The investigation was not successful from the standpoint of the original purpose, but an examination and analysis of the data shows the status and extent of the industry and the markets for its products and gives a general insight into the hardwood distillation industry.

Bureau of Census Circular Forest Products No. 7, "Wood Distillation, 1910," reports 117 plants engaged in the destructive distillation of hardwoods. These plants consumed 1,258,000 cords of wood in the process. At the time of this investigation 110 plants were known to be operating with an estimated consumption of 1,250,000 cords per annum.

THE DATA OBTAINED.

Only about 60 of the plants furnished the information desired. In the data as tabulated, instead of giving the actual figures obtained an estimated total production of each product is given. This estimate was made by assuming that the average production of each plant which failed to report is probably very nearly equal to that of the average plants that did report. The production of an average plant was calculated from the actual data by disregarding the production of the three largest reporting plants (except in the case of charcoal, for which the six largest producers were not included) and determining the average production of all the others.

[1] The statistical data on which this report is based were collected by the Office of Wood Utilization.

In the case of each standard product this calculated total is only slightly higher than that reported by Bureau of the Census Circular Forest Products No. 7, "Wood Distillation, 1909." It therefore seems safe to assume that the totals are probably not far from correct.[1] However, the data can not be considered more than a careful estimate for several reasons:

1. Request for data was sent to 110 distillation plants, of which 61, or only 55 per cent, replied.

Table 1.—*Reported and estimated production of plants engaged in the destructive distillation of hardwoods.*

Product.	Reported production 1910.	Estimated production 1910 from this report.
Charcoal.....bushels..	56,147,869	60,565,687
Gray acetate of lime.....pounds..	152,772,220	154,000,000
Brown acetate of lime.....do....	3,321,122	2,160,000
Iron acetate liquor.....gallons..	248,104	352,000
Crude alcohol.....do....	8,691,525	9,796,356

2. A large number of the plants (*a*) either report their products as being sold to large agencies or to commission firms, (*b*) or state that they do not know what industry uses the product, (*c*) or fail to answer the questions. The fact that the products were sold to large holding companies probably is the reason for both (*b*) and (*c*). This is particularly true for both gray acetate of lime, of which 64 per cent is sold to one agency, and crude wood alcohol, of which 47.5 per cent is sold to one large refinery and 21.7 per cent to "other refineries." It is evident in both cases that the ultimate consuming industries could not be determined from the data given except by the method used.

It is probable that both the price and production of gray acetate is controlled very largely by this one selling agency. However, in the case of crude wood alcohol the one large refining company and other similar companies probably serve more as central refiners, owing to the large amount of expensive apparatus necessary for that process, prohibiting its practice by the smaller plant rather than controllers of the price and production of the article. As the statistics given in Tables 1 to 4 are more specific than the above discussion would lead one to expect, a brief explanation of the data shown is necessary.

1. CHARCOAL.

In the case of charcoal, one selling agency handles the product of five or six plants, probably all supplying a domestic trade and representing 2.75 per cent of the total. However, it is probable that a number of other plants in the same locality that reported their charcoal for

[1] Since making this estimate of production, the following authentic data have been received, giving amount of products for 1910. These data are given here for comparison with the estimated production in order to show the correctness of the estimate.

"domestic" uses also sell through this agency, which would bring up the proportion of the total to 15 per cent or more. Practically one-half of the plants produce charcoal for their own use in making charcoal pig iron or other blast-furnace products, in connection with the plant itself, representing 77 per cent of the total product. The product of all plants neglecting to designate the industry to which their charcoal was sold was considered as "domestic."

TABLE 2.—*Quantity and price of charcoal sold to each market.*

[Reported production (61 plants) 831,313,747 pounds, or 41,565,687 bushels. Total production (estimated for 110 plants) 1,211,313,747 pounds, or 60,565,687 bushels.]

Number of producing plants.[1]	Market.	Amount consumed.		Average selling price per bushel.[2]	Total production to each market.
		Pounds.	*Bushels.*		*Per cent.*
60	Blast furnace	923,625,732	41,181,286	$0.0692	76.25
66	Domestic (hotels and peddlers)	236,206,180	11,810,309	.0706	19.5
6	Controlling agency (also domestic)	33,311,127	1,665,556	.061	2.75
2	Chemical uses	23,014,961	1,150,748	.10	1.9
7	Powder mills	12,476,531	623,826	.064	1.03
4	Tin smelters	1,332,445	66,622	.096	.11
4	Copper smelters	847,919	42,395	.102	.07
2	Railroads	726,848	36,342	.10	.06

[1] Forty plants reported their product to more than one market.
[2] The maximum selling price was $0.134 and the minimum $0.05.

2. ACETATE.

A few plants reported this product as "exported," so it was thought best to determine the total export. The figures for this were taken from the Oil, Paint, and Drug Reporter's Review of Chemical Trades for 1910, Volume LXXIX, No. 9, pages 81 and 82.

Sixty-four per cent of the total acetate is handled by one selling agency, this value including all acetate not designated to any industry, representing one-third of the 64 per cent.

An inquiry to this controlling company gave the information that 75 per cent of the acetate consumed in this country was made into acetic acid and 25 per cent into acetone. The data showing the distribution by this selling company were then determined as follows: The export reported direct from plants was taken from the known total export and the balance of the export figure was made up from the total reported to the agency. The remainder of the acetate assigned to them was then proportioned to the acetic acid and acetone industries as stated above.

The ultimate consuming industries for gray acetate as far as determined from the data are summarized in Table 3. The high export, 40 per cent, is worthy of note, but it is unfortunate that no estimate can be made of its final use in other countries.

It is well known that acetic acid finds a large commercial use (1) in the cotton and woolen industries as mordants, (2) in the manufacture of organic dyes, (3) for numerous medicinal uses, and (4) in chemical

laboratories, but no idea of the proportion to each can be determined from these data.

TABLE 3.—*Quantity and price of gray acetate of lime sold to each market.*

[Reported production (61 plants [1]—50 producing acetate), 96,000,000 pounds; estimated total production (110 plants—90 producing acetate), 154,000,000 pounds.]

Number of producing plants.[2]	Market.	Amount consumed.	Average selling price per pound.[3]	Total production to each market.
		Pounds.		*Per cent.*
60	1 controlling agency	98,700,000	$0.0167	64
	(*a*) Export, 56 per cent	55,410,100	.....	35.8
	(*b*) Acetic acid manufactures, 33 per cent	32,450,000	.....	21.1
	(*c*) Acetone manufactures, 11 per cent	10,839,900	.....	7.1
40	Worked up at plants	20,630,000	.....	13.5
	(*a*) Acetic acid, 33 per cent	7,010,000	.....	4.6
	(*b*) Acetone, 66 per cent	13,620,000	.....	8.9
11	Export direct from plants	8,290,000	.01725	3.5
20	Chemical manufactures, miscellaneous	26,370,000	.016	17
	Total to acetic acid manufactures	139,460,000	.....	25.7
	Total to acetone manufactures	24,599,000	.....	16.0
	Total exported	63,700,000	.0224	41.3

[1] A number of distillation plants produce only charcoal.
[2] Four plants reported to more than one market.
[3] The maximum selling price was $0.025 and the minimum $0.0125.

TABLE 4.—*Quantity and price of other acetate products sold to each market.*

Number of producing plants.	Product.	Market.	Amount consumed.	Average selling price.	Total production to each market.
					Per cent.
2	Brown acetate	Acetic-acid manufactures, pounds.	2,160,000	$0.0116	100.0
4	Iron acetate	Finishing-cotton dyes, gallons.	290,000	.095	82.5
2	.....do	Black dyeing.....gallons	62,000	.10	17.5
2	Wood acid	Stove-company dyes, gallons.	12,000	.09	100.0

It is also known that acetone is largely used commercially (1) in the manufacture of smokeless powder, (2) as a solvent for acetylene for automobile lights, (3) as a solvent in numerous chemical industries, and (4) in medicinal manufacture, such as for chloroform, iodoform, and sulphonal; but, here, again, no idea of the proportion to each can be estimated.

3. ALCOHOL.

The consuming industries for this product are given more fully in the data than for either the charcoal or acetate. As in the case of the other products, a number of plants did not designate the buying industry for this product. These were considered as selling to the largest consumer, one large refinery, 47 per cent of the total production of crude wood spirit being refined by them.

The data showing the commercial uses of the refined wood alcohol produced by this refinery were supplied by them upon request.

Excepting the plants that refine their own crude, all the others reported their product as crude alcohol (82 per cent). In every case, however, the amount has been calculated to refined (95 to 97 per cent).

Since it is known that a large quantity of alcohol is exported, it was thought advisable to include the export for this product with the other data. The figures for this were taken from the Oil, Paint, and Drug Reporter's Review of Chemical Trades for 1910, Volume LXXIX, No. 9, pages 81 and 82. None of the plants reported any export; and as the one large refinery referred to supplies only domestic industries, the export figure was subtracted from the quantity reported to "other refineries."

The total production of wood alcohol is summarized according to using industries in Table 5.

TABLE 5.—*Quantity and price of wood alcohol sold to each market.*

[Reported production (61 plants—53 producing), 6,159,356 gallons crude; 4,925,000 gallons refined. Total production, estimated (110 plants—93 producing), 9,796,356 gallons crude; 7,800,000 gallons refined.]

Number of producing plants.	Market.	Amount consumed.		Average selling price (crude).[1]	Total production to each market.
		80 per cent crude.	96 per cent refined.		
		Gallons.	*Gallons.*		*Per cent.*
48	One large refinery	4,625,500	.....	$0.2494	.....
	(*a*) 95 per cent alcohol, 80 per cent	3,700,000	3,080,000	.....	38.5
	1. Paint and varnish, 75 per cent	2,775,000	2,315,000	.....	28.5
	2. Celluloid manufacturing, cleaning, and burning, 25 per cent	925,000	770,000	.....	9.5
	(*b*) Methyl acetone, 15 per cent	693,000	.....	.....	7.13
	1. Paint and varnish removers.				
	2. Manufacture of gas mantles.				
	3. Solvent for difficultly soluble gums.				
	4. Preparation of lacquers.				
	(*c*) Pure methyl alcohol, 5 per cent	231,000	184,800	.....	2.37
	1. Formaldehyde, 25 per cent	57,800	46,000	.....	.59
	2. Photographic films, 15 per cent	34,700	27,000	.....	.36
	3. Synthetic oil of wintergreen, 10 per cent	23,100	18,480	.....	.29
	4. Manufacturing chemists, 45 per cent	104,000	82,700	.....	1.13
2	Wholesale drug companies	171,750	144,800	.30	1.75
4	To paint manufacturers direct from plants	244,800	187,500	.275	2.3
9	Refined at plants	2,653,000	2,213,000	.....	27
	1. Formaldehyde, 21.4 per cent	568,000	474,000	[2].42	5.75
	2. Chemical and wholesale drug companies, 38.6 per cent	1,025,000	855,000	.....	10.45
	3. Shellac solvent, 16.1 per cent	427,500	368,000	.....	4.35
	4. Varnish manufacture, 23.9 per cent	635,000	529,000	.....	6.45
30	Other refineries	2,131,000	1,775,000	.244	21.7
	Total to paint manufacturers for shellac and varnish	4,026,300	3,197,000	.....	40.8
	Total to wholesale drug companies	1,196,750	999,800	.....	12.2
	Total to miscellaneous chemical industries:				
	1. Formaldehyde manufacture	625,600	520,000	.....	6.34
	2. Photographic films	34,700	27,600	.....	.36
	3. Synthetic oil of wintergreen	23,100	13,480	.....	.29
	4. Celluloid manufacture, cleaning and burning	925,000	770,000	.....	9.50
	5. Manufacture of methyl acetone	693,000	.....	.....	7.13
	(*a*) Paint and varnish remover.				
	(*b*) Manufacture of gas mantles.				
	(*c*) Solvent for various gums.				
	(*d*) Preparation of lacquers.				
	Total	2,301,400	1,336,080	.....	23.62
	Other refineries than the 1 large refinery	2,131,000	1,775,000	.....	21.7
	1. Manufacture of denatured alcohol	1,301,000	.....	.....	13.25
	2. Exported	830,000	692,000	.....	8.45

[1] The maximum selling price was $0.328 and the minimum $0.20, probably depending to a large extent on purity.

[2] Refined.

It is of interest to note that over 40 per cent is used by the paint and varnish manufacturers.

In view of the increasing use of industrial or denatured alcohol, it is unfortunate that no more definite figures were given showing the extent of the use of wood alcohol as a denaturant; but it is probable that a considerable proportion, probably 20 per cent of the refined, of the product handled by other large refineries is used for that purpose.

USES FOR WASTE PRODUCTS.

The result of the second purpose of the investigation, to find possible markets for by-products now being wasted, is practically negative. Only two plants reported any market for tar or tar products, one plant selling "wood oil" to "chemical companies" for 8½ cents per gallon, "wood creosote" and "wood tar" to "chemical companies" for 4½ cents per gallon, and the other plant selling "oils" at 8 cents per gallon, but failing to designate the market. It is probable that a few other plants find small special markets for tar products and do not wish, for obvious reasons, to have the market known; but the large majority of plants either burn their tar as an economy of fuel for the distillation process or throw it away.

SILVICULTURAL INVESTIGATIONS.

SEED STUDIES.

THE GERMINATION OF ALLIGATOR JUNIPER SEED.

FORT BAYARD NURSERY.

HARRY C. TURNER, *Planting Assistant.*

Alligator juniper (*Juniperus pachyphlœa*) is one of the most common and valuable trees of the woodland type in the Southwest. It occurs in the lower mountain regions of Arizona and New Mexico between elevations of 5,000 to 7,500 feet. The wood is valuable mainly for fuel and fence posts, being nearly as durable in contact with the soil as the one-seed juniper, one of its associates. Wherever there has been a market for wood where cutting has been unrestricted the juniper has been thoroughly cleaned out, in many places the less valuable piñon having been left to occupy the ground.

The junipers depend on birds and mammals for the dissemination of their seed, and for this reason reproduction is rather uncertain in this region. Junipers as a class stand planting well, but it has always been difficult to propagate them in the nursery, because of the slowness and uncertainty of germination. In nature germination is promoted by the seed passing through the alimentary tracts of birds or mammals. The berries are commonly eaten by foxes, coyotes, and birds. Seedlings are often found near fences and under trees of other species, and in one instance the writer counted 11 seedlings growing in a pile of horse manure. Ordinarily, if planted in the nursery bed without any previous preparation, the seed will not germinate until the following season, and very likely not at all.

At the Fort Bayard nursery a process was successfully used in 1910 and 1911 by which the seed of alligator juniper may be made to germinate the same season that it is sown. The idea of stratifying the seed, as hereinafter described, was suggested by the practice with *J. virginiana* at Kansas Agricultural College in 1906. There, however, the seed lay in the sand over one season, no attempt being made to cause it to germinate the first year.

GATHERING THE BERRIES AND SEPARATING THE SEED.

The seed of alligator juniper requires two seasons to mature, and often there are two crops of seed on the same tree at the same time. As the unmatured berries at the end of the first season are often apparently full grown, care must be exercised to distinguish them from the mature ones. The mature berries are of a brownish color, while the immature ones are bright green. The immature seed is easily crushed between the teeth, while the mature seed is too hard for this. Individual trees also vary greatly as to the percentage of fertile seeds they bear, as is the case with all junipers. Therefore care should be exercised to test the seed from each tree before the berries are gathered. This may be done by cutting open 100 seeds which are representative of the crop on the tree. As is the case with all seeds, the larger ones are more likely to be fertile, and therefore in gathering seed one should be on the lookout for trees with large berries. The berries ripen and fall off the trees irregularly, beginning in August. They may be picked off the trees or off the ground after they have fallen or knocked off the tree and allowed to fall upon sheets, providing there are only mature berries on the tree.

There are several methods of separating the seeds from the berries. The following method has been used by the writer with success:

Use a 2 by 6 inch scantling 2 feet long; saw grooves 1 inch apart by one-fourth inch deep diagonally across the face the entire length; on each side of the saw cut, one-half inch back, chisel slopingly to bottom of each groove, evenly, the width of the board so as to resemble a washboard. Then saw two pieces 2 by 12 inches 2 feet long; place one on each side of the corrugated piece and fasten tightly together by means of cleats tacked on the under side—three cleats should be used to hold securely in place. Then saw a piece of 2 by 6 inches 8 inches long for a hand piece.

Spread a wagon sheet or tarpaulin on a smooth piece of ground; place the grooved board on center of sheet; fill the grooves with berries and rub downward with the hand piece until all are mashed; then scatter the pulp evenly over the sheet and place it on the sunny side of a building, or some place where the sun's heat is greatest, to insure a thorough drying. After the berries are thoroughly dry, rub on another board similar to the above, excepting that the surface is smooth, until the seeds are free from the pulp. To separate seed from pulp use a tub; fill about two-thirds full of water and pour pulp in evenly and gently to the amount of 5 or 6 pounds; stir lightly and skim off waste with a skimmer or piece of door screen. Repeat until all seed has been separated. Avoid putting too much pulp in water at once. The cleaned seed should be spread out until thoroughly dry, then stored in sacks in a cool place.

STRATIFICATION OF SEED.

Stratifying the juniper seed is the next step in preparing them for germination after they have been separated from the berries. If it is desired to sow the seed in the spring, the stratifying should be done the preceding fall or winter. Any ordinary sized box, such as is used in packing canned goods, etc., may be used. Several small holes should be bored in the bottom of the box to afford drainage.

A hole should be dug on a site facing the south. It should be large enough to let the box into easily, and about 6 inches deeper than the box. The bottom of the hole should be leveled up so that the box will sit squarely on the ground. A layer of sand about three-fourths inch thick is spread evenly over the bottom of the box. A layer of seed about two seeds thick is spread on the sand, then a layer of sand, and so on until the box is nearly full. About two or three inches of sand should be spread on top, and a depression left in the ground over the box.

The seed should be watered thoroughly after being stratified and as often afterwards as is necessary to keep the sand moist. This will not call for much attention until the following spring when dry weather sets in. Ordinarily the seed will begin to germinate about May 1, but it should be examined a week or two before this and at intervals of three or four days thereafter. It may show no signs of germination one day, and a week afterward be so far along that many of the sprouts will be broken off in handling. The seeds will not all be ready to germinate at once, but should be sown as soon as the first ones are ready. Contrary to expectations, the seeds in the bottom of the box were found to be just as far advanced as those in the top layer.

Seed sown in the summer rainy season should be stratified in the spring instead of the fall, about the last of May or the first week in June. In four or five weeks they will begin to germinate. This is the best plan, unless it is desired to raise stock as large as possible the first year. Juniper is not affected by damping off, so this objection to sowing during the rainy season does not apply to it. In any event, the seed bed should be prepared in advance, so that the seed may be sown without delay when it is ready.

PREPARATION OF SEED BED.

The following preparation of seed beds has been found satisfactory. The bed is spaded to a depth of about a foot and all lumps broken up. Soil is raked off the bed on all sides and left in a bank about 6 inches high all around the edge. The basin thus formed is filled with water. In about 24 hours after the water settles the banks of soil around the edges are replaced on the beds, and the surface

leveled off to prevent drying out. The surface may now be prepared for seeding at any time.

Two pounds of seed of 50 per cent germination is sufficient for 48 square feet of seed bed, if sown broadcast. The seed should be scattered as evenly as possible over the surface. As an aid to uniform sowing the bed may be marked off into a number of equal areas, and a proportionate amount of seed scattered over each area. The seed is pressed into the soil with the back of a hoe, and about one-fourth of an inch of sand scattered over the surface. Sand is decidedly better than soil for covering both pine and juniper seed, especially if sowing is done in dry weather. The crust which forms on soil surface after watering hinders germination, makes thorough watering difficult, and dries out faster than a sanded surface. The sand should be rather coarse, but if it contains many large pebbles it should be screened. As soon as the sand is applied the bed should be watered.

In some respects sowing in drills 4 or 5 inches apart is preferable to sowing broadcast. Seedlings in drills may be cultivated and thus make a more vigorous growth than if the seed is broadcasted. Moreover, juniper seedlings at this nursery are subject to either a blight or insect attack which cuts the roots a short distance below the surface, and cultivation appears to prevent this trouble to a large extent.

If the sowing is done during very dry weather it is advisable, and in fact almost necessary, to cover the bed with burlap. The burlap may be covered over with about half an inch of soil to conserve moisture, or else watered as often as necessary to promote germination. Generally the blanket of dry soil will keep the seed moist enough till they begin to germinate, and is preferable to frequent watering, which always cools the soil through rapid evaporation. If sowing is not done till the beginning of the summer rainy season it will not be necessary to use any covering to conserve moisture.

SUBSEQUENT TREATMENT.

Germination will begin in from 6 to 10 days after sowing. If burlap is used it should be removed a few days after germination begins, and a lath shade put over the bed immediately to protect the tender seedlings. Germination proceeds quite slowly, and if the weather is dry watering must be done often enough to prevent the seeds from drying out. If the surface has been sanded a thorough watering not oftener than once in three or four days will be sufficient. As soon as germination is completed the shade may be removed. If the seed has been sown in drills the bed should be cultivated occasionally. Cultivated beds will require less water than uncultivated ones. For the former a good watering once in two weeks is sufficient.

EFFECT OF SOURCE OF SEED ON RESULTS IN YELLOW-PINE REFORESTATION

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

The purpose of this experiment, started in 1910, was to determine the relative germination and rate of growth of seedlings and nursery stock of yellow pine, from seed obtained in the north range, south range, and middle range of the species, when sown and planted on situations of different heat and moisture qualities at the middle of the range.

LOCATION.

The three sites on which the tests have been conducted are as follows:

1. Elevation, 8,800 feet; slope, 15 per cent SW.; ground cover, heavy grass and scattering bearberry.
2. Elevation, 8,900 feet; slope, 30 per cent S.; ground cover, scattering grass and bearberry.
3. Elevation, 8,100 feet; slope, 50 per cent SE.; ground cover, scattering oak and yucca.

All three are in the yellow-pine type, though No. 3 borders on the piñon-juniper type.

OPERATIONS.

In 1910 the work consisted in sowing seed from the Boise, Coconino, and Pike Forests in seed spots at the three sites. In 1911 the work was confined to planting nursery stock from seed obtained near the southern limit of the species, grown at Fort Bayard Nursery, and from seed obtained near the center of the range, grown at Monument Nursery. No stock from northern seed was obtained this season.

RESULTS.

The results in 1910 indicated the utter futility of sowing seed on steep gravelly slopes, and showed that native seed germinated best and produced the hardiest seedlings on the more favorable sites. The results of seed sowing at site 3 were so poor as to be practically negligible.

Table 1 shows the number of plants living at the time of various counts, the death during the first winter and second summer, and the second-year germination:

Table 1.—*Results of 1910 seed sowing.*

No. of site.	Source of seed.	Number of plants living.				Deaths during—		Germination.	
		Fall, 1910.	Spring, 1911.	Summer, 1911.	Fall, 1911.	Winter, 1910–11.	Summer, 1911.	New, 1911.	Total, 1910–11.
1	Pike Forest	36	24	24	21	12	7	4	302
	Coconino Forest	17	1	10	2	16	9	10	35
	Boise Forest	10	6	7	6	4	1	1	46
2	Pike Forest	23	13	12	12	10	1	0	72
	Coconino Forest	20	7	18	6	13	14	13	77
	Boise Forest	2	2	2	2	0	0	0	24
3	Pike Forest	0	0	0	0	0	0	0	8
	Coconino Forest	0	0	0	0	0	0	0	24
	Boise Forest	3	0	0	0	3	0	0	13
	Total:								
	Pike Forest	59	37	36	33	22	8	4	382
	Coconino Forest	37	8	28	8	29	23	23	136
	Boise Forest	15	8	9	8	7	1	1	83

The moisture content of the soil in the various plots during the seasons of 1910 and 1911 is given in Table 2 for the purpose of showing the uniformity of opportunity for growth given the seed from various sources.

Table 2.—*Moisture content of soil in plots sown in 1910.*

No. of site.	Source of seed.	Soil moisture, 6 inches depth.			
		Spring.		Summer.	
		1910	1911	1910	1911
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
1	Pike Forest	9.54	13.68	3.97	9.07
	Coconino Forest	7.54	11.51	4.20	9.22
	Boise Forest	7.07	9.91	3.72	9.89
2	Pike Forest	5.03	9.55	2.86	6.91
	Coconino Forest	3.90	6.89	2.39	8.45
	Boise Forest	4.59	7.38	3.23	9.39
3	Pike Forest	5.78	.....	1.90	.....
	Coconino Forest	4.97	.....	1.83	.....
	Boise Forest	8.11	.....	2.44	.....
	Average:				
	Pike Forest	6.78	11.61	2.91	7.99
	Coconino Forest	5.47	9.20	2.81	8.83
	Boise Forest	6.59	8.64	3.13	9.64

Table 2 shows that while in both sites 1 and 2 the plots on which Pike seed were sown were more moist than the others in the spring, they became drier in the summer, so that the seedlings which had appeared were subjected to a greater test than the seedlings from

northern and southern seed, and a heavier weeding out occurred before the end of the first season.

In view of this fact, the superiority of the local seed and the seedlings therefrom is quite apparent. Had the more favorable conditions of germination in the spring of 1910 materially affected the Pike seed, the seedlings would have been less hardy, not more hardy, than those from other sources. As it was, during the first winter 37 per cent of the Pike seedlings succumbed, as against 61 per cent Coconino and 47 per cent Boise, and during the second summer, of the seedlings living in the spring, 20 per cent from Pike, 74 per cent from Coconino, and 22 per cent from Boise seed dropped out.

While the number of seedlings surviving in the fall of the second year is in all cases small, the results are usually not bad for average yellow-pine sites, and the results with the Pike seed are plainly the best all the way through.

It is worthy of note that there was considerable new germination during the second season, particularly from the Coconino seed. This is contrary to the usual rule which gives the most vigorous and rapid germination to seed from southern sources.

Table 3 shows the source and quality of the stock used in 1911.

TABLE 3.—*Stock used, 1911.*

Source.		Age.	Size of tops.	Size of roots.
Seed.	Stock.			
		Years.		
New Mexico	Fort Bayard Nursery	1–1	3–4 inches, stocky.	6–8 inches, few fibrous.
Pike National Forest	Monument Nursery	1–1	do	6–8 inches, many fibrous.
Do	do	2–2	6–7 inches, fairly stocky.	8–12 inches, many fibrous.

The planting was all done about April 15, being delayed about three weeks beyond the proper date owing to failure in shipment of Fort Bayard stock. Growth had already started on this when received, which undoubtedly affected the results somewhat. The Monument stock had been heeled in in a cool place and was in perfect condition; 100 plants from both sources were planted at both sites 2 and 3, spaced 4 by 4 feet, using the cone method and mulching each plant with grass and leaves. Of the Monument stock, 50 each of the 2–2 and 1–1 stock were used at each site. Table 4 shows the results.

TABLE 4.—*Growth of stock planted, 1911.*

No. of site.	Stock.		Plants living.						Soil moisture.	
	Source.	Age.	May.	July.	Aug.	Sept.	Oct.	Dec.	Spring, 1911.	Summer, 1911.
		Years.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
2	Fort Bayard Nursery	1-1	78	.....	40	14	.....	11	10.89	6.41
	Monument Nursery	1-1	98	.....	92	92	.....	90	9.42	7.56
	Do	2-2	98	.....	77	54	.....	37	13.02	5.72
	Average	.....	98	.....	84	73	.....	64	11.49	7.03
3	Fort Bayard Nursery	1-1	88	39	34	.....	14	.....	6.72	2.12
	Monument Nursery	1-1	92	[1] 65	77	.....	69	.....	7.26	2.91
	Do	2-2	98	[1] 64	62	.....	54	.....	7.02	2.74
	Average	.....	95	[1] 64	69	.....	63	.....	7.07	2.62
	Fort Bayard Nursery (average)	1-1	83	39	24	.....	12	.....	8.80	4.26
	Monument Nursery	1-1	95	[1] 78	89	.....	79	.....	8.34	3.23
	Do	2-2	98	[1] 70	58	.....	45	.....	10.02	4.26
	Average	.....	96	[1] 74	71	.....	64	.....	9.28	4.82

[1] Counts of the Monument stock made in July are not reliable. The death rate at site of test No. 3 has been materially increased by gravel sliding over and burying plants, and by rabbits. Over half the plants now living in both plots at this site have been badly chewed by rabbits, in most cases the tip buds having been devoured.

The same marked difference was noted this year as last between the quality of the stock received from Fort Bayard and Monument nurseries, that from Monument being vastly superior in stockiness of tops and fibrous root systems. This may be due to quality of soil and methods of handling in the nurseries themselves, just as much as to source of seed from which grown and climatic differences of nurseries.

CONCLUSIONS.

1. The greatest germination is shown by local seed, while the poorest is shown by northern seed.

2. The hardiest plants, those having the largest percentage of total germination still living, are produced by seed from the northern source, while the weakest plants are produced by the southern seed.

3. Seed from the southern source shows a much more marked tendency to lie over and germinate the second season. On the other hand, of the 23 seeds from this source germinating the second summer, in the field sowing, 21 died, showing a markedly poor quality.

4. As between the various sites, the seed from the middle and northern sources have done best on the most favorable site (1), while the southern seed has done best on the moderately favorable site (2). Seed from all three sources has failed on site 3, where conditions are so bad as to make seed sowing absolutely futile.

5. Stock grown at Monument Nursery from local seed is much superior to that grown at Fort Bayard Nursery from New Mexico

seed, though whether this is entirely due to the source of the seed and the geographical location of the nurseries is open to question.

6. 1–1 stock is superior to 2–2 stock for planting, though the larger stock does proportionately better on the more severe site. This superiority of the 1–1 stock becomes even more apparent when it is noted that it cost only $2.41 per thousand, while the 2–2 stock cost $13.57.

7. In the way of practical recommendations it is suggested that extreme care be used in this district to avoid shipments of yellow-pine seed from one latitude to another. It is believed to be of the greatest importance to avoid shipping yellow-pine seed northward, for, even though southern seed is in general more vigorous in its germination and more likely to take advantage of temporarily favorable moisture conditions, it is very probable that the seedlings will prove unhardy in a more northern latitude than that to which they are accustomed. The bases for this statement are found in the following facts:

(*a*) Experience with yellow-pine direct seeding has shown that the period of greatest loss of seedlings is in the winter and early spring, when, in the zone of this species, the ground is frequently bare, the soil and the plants dry out, and plants are heaved out by frost.

(*b*) A study of climatic conditions within and just outside the yellow-pine type throughout this district shows that one of the most important factors in limiting the natural distribution of the species is the amount of the snowfall. In other words, yellow pine does not seem to be able to reproduce naturally where the normal snowfall drops below a certain point (about 1 inch of water per month).

(*c*) It is characteristic of the region that in the yellow-pine type the snowfall is heavier at the southern latitudes than at the northern. (Compare Durango, or Coconino Station, with Boulder or Deadwood.) This means that if yellow pine is moved northward it is more exposed, by lack of snow covering, during the crucial months of its existence than it has been accustomed to be, and not only this, but it is more liable to be struck by extremely cold winds and also by chinooks. A striking example of this effect was to be seen in the Black Hills (Roubaix Plantation) in the spring of 1911. So far as is known, only this plantation, mostly grown from inported seed, was affected in the winter of 1910–11.

Owing to the almost complete failure of the Coconino and Boise seed to produce seedlings in the nursery, from the sowing of 1910, the original plan of completing a small stand of trees from each of the three sources and studying their comparative growth can not be carried out. However, there has been sown in 1912 seed of yellow pine from 10 different sources within District 2, and the experiment will be continued in a study of the effect of smaller latitudinal differences in the source of seed on both the germination and survival and the qualities of the trees produced.

STUDIES OF SPECIES, METHODS, AND SEASONS FOR ARTIFICIAL REFORESTATION.

METHODS AND SEASONS FOR YELLOW-PINE REFORESTATION.

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

The purpose of this experiment, begun in the winter of 1909–10, was to determine the best method and season for yellow-pine reforestation on typical ground for this species along the front range of the Rocky Mountains. The conclusions are to be based on the cost of establishing a reasonably good stand of seedlings at the age of 2 or 3 years.

LOCATION.

The experiment has been carried on at the Fremont Experiment Station at an altitude of 8,800 feet, which is approaching the upper limit of the yellow-pine type in this locality, although the tree is found to some extent up to 9,500 feet. The site chosen is a 10-per-cent south slope, having a loamy gravelly soil made up from the disintegration of granite, and to some extent built up by the deposition of silt from the slope above. The soil cover is a heavy sod of native grasses. A few thrifty yellow-pine seedlings from 3 to 6 feet high are found on the area, while at the upper edge appears practically a normal stand of mature yellow pine.

OPERATIONS.

The operations in this experiment comprise comparisons of the value of spring, summer, and fall sowing under four different methods, and of spring, summer, and fall planting. The methods of sowing were (1) broadcasting without preparation of the soil, (2) broadcasting after thorough harrowing of the soil, (3) corn-planter sowing, and (4) sowing in prepared seed spots of about 1 foot diameter and a depth of 3 inches. The broadcasting on unprepared ground was done on snow in late winter as well as at the other three seasons. In broadcast sowing 5 good seeds were used per square foot; in seed-spot sowing, 20 good seeds per spot; and in corn-planter sowing, approximately 10 good seeds per spot. The seed used was of local collection and had a germinative capacity of 77 per cent. The stock used in the planting of 1910 was 2–1 transplants from the Monument Nursery, while in 1911 2-year seedlings were potted in April and planted in July, while 2–1 transplants were heeled-in in April and

planted in July. Thus, practically all of the stock used was of the same age. The area required for each operation was a plot 40 by 40 feet, comprising approximately one twenty-fifth of an acre.

RESULTS.

The results of the various operations are shown in Table 1.

TABLE 1.—*Results of various methods at end of second year.*

Method.	Season.	Total germination.	Seedlings surviving.		Percentage of total germination surviving, fall, 1911.
			Fall, 1910.	Fall, 1911.	
					Per cent.
Broadcasting, no preparation	Winter	0	0	0	.....
	Spring	5	5	0	0
	Summer	34	12	1	3
	Fall	0	.....	0	.....
Broadcasting, harrowed ground	Spring	131	71	30	23
	Summer	971	491	107	11
	Fall	0	.....	0	0
Corn-planter sowing	Spring	0	0	0	0
	Summer	29	28	0	0
	Fall	91	.....	[1] 90	99
Prepared seed spots	Spring	448	151	105	24
	Summer	100	48	22	22
	Fall	66	.....	16	24
Planting direct from nursery	Spring	.....	68	68	.....
	Summer	.....	6	4	.....
	Fall	.....	90	29	.....
Planting, potted	Spring [2]	.....	.....	66	.....
	Summer [2]	.....	.....	93	.....
Planting, heeled-in	...do.[2]	.....	.....	79	.....

[1] Counts made in late summer. [2] Planting in 1911.

CONCLUSIONS.

1. Broadcast sowing without preparation of the soil in no case produced even a fair amount of germination, and from the small amount of germination secured by the summer sowing only one seedling survived to the end of the second year. The complete loss of the seedlings is undoubtedly due to their inability to compete with the native vegetation, which was undisturbed.

2. Broadcast sowing on thoroughly harrowed ground was much more successful. The greatest success was obtained with the midsummer sowing, which was followed, as in the normal year, by fairly frequent rains, so that the shallow covering given was adequate. The summer-sown seedlings were less thoroughly ripened and did not survive the first winter quite as well as those from spring sowing. The number surviving at the end of the second year, however, is adequate to make a good stand.

3. The corn-planter sowing failed for practically the same reasons as the broadcast sowing on unprepared ground. It has the additional disadvantage of inviting destruction of the seed by rodents, since the seed are placed in small pockets, which are easily reached. The success of the fall corn-planter sowing can hardly be compared with

that of the spring and summer sowing, since the fall seedlings when last counted had not yet passed through an entire growing season.

4. Seed-spot sowing produced a fair per cent of germination at all times, but the spring work produced especially good results. The advantage of spring seed-spot sowing is doubtless due to the fact that the preparation and loosening up of the soil conserves the moisture found therein in the early part of the year and these small beds do not dry out during the June drouth period, as appeared to be the case on unprepared ground.

5. The spring planting is unmistakably the best, although trees which had been specially prepared and which were planted at the beginning of the rainy season in 1911 have done remarkably well. There was practically no loss among spring-planted trees after the end of the first summer.

Considering now the relative merits of the different methods of reforesting in the yellow-pine type, and selecting in each case the season which has shown itself to be most favorable, the relative costs may be obtained from Table 2.

Table 2.—*Comparison of methods on basis of costs.*

Season and method.	Thrifty trees, fall, 1911.	Total cost.	Cost of each surviving tree.
Summer, broadcast, unprepared	1	$1.07	$1.07
Summer, broadcast, harrowed	107	1.45	.0136
Spring seed-spot sowing	105	1.39	.0132
Spring planting	68	2.55	.0375
Summer planting:			
Potted	93	6.41	.0689
Heeled in	79	3.83	.0485

The figures given above show quite clearly that even where moisture conditions are quite favorable for yellow pine, as was the case on the selected site, the method of reforestation which requires the greatest amount of preparation is, in the end, the cheapest. Considering the cost of each tree, the least expensive method of obtaining a stand is by spring seed-spot sowing. Next in order comes summer broadcasting on harrowed ground (where this is possible), and following this the spring planting of sturdy nursery stock. The results of broadcasting on unprepared ground are such as to prohibit its use where the ground cover is of sod. The use of either potted or cold-stored transplants produces good results, but the additional expense necessary for successful summer planting is not warranted where the spring moisture conditions are as favorable as in this locality.

The experiment is to be repeated in 1912, both in this immediate vicinity and under different soil conditions on the San Isabel National Forest. In view of the apparent advantage gained by destroying the sod as in seed spots, new methods are being tried which it is thought will give the same physical conditions with less expense.

PLANTING WESTERN YELLOW PINE.

FORT VALLEY EXPERIMENT STATION.

G. A. Pearson, *Forest Examiner.*

OBJECT.

Because of the uniform failures in planting western yellow pine in this region in the past, the primary purpose of this experiment was to determine whether, by using the best available stock and the best-known methods, it would not be possible materially to improve upon the results of past years. In order to eliminate, as far as possible, all unknown factors, it was decided to use only the best-developed home-grown stock, the handling of which could be supervised from the time it was dug in the transplant bed until planted in the field.

Incidentally opportunity was furnished to test different kinds of stock, planting sites, and planting methods; but this phase of the experiment was not emphasized, because such experiments in the past have been entirely vitiated by the almost total failure of all plantings, regardless of methods, sites, and classes of stock.

LOCATION.

Area A, Fort Valley.—Elevation, 7,300 feet; pure western yellow-pine stand cut moderately 15 years ago; scattering stand of saplings and seedlings; "malpais" (volcanic) formation; soil a clayey loam mixed with volcanic rock fragments of all sizes, with adobe subsoil; no sedimentary rocks within 50 feet of the surface; ground cover scattering grasses and weeds; no underbrush; situation practically level mesa, fairly well protected by timber.

Area B, Flagstaff.—Elevation, 7,200 feet; formerly pure western yellow-pine stand, clean cut 25 years ago, now covered with heavy growth of bunch grasses; no natural reproduction; limestone formation, with considerable outcrop; soil light, sandy loam, rocky in places; rolling mesa exposed to full force of the wind.

Table 1.—*Meteorological records for the growing season.*

AREA A, FORT VALLEY.

Month.	Mean temperature.	Wind, daily.	Precipitation.	Total evaporation.[1]
	°F.	*Miles.*	*Inches.*	*Inches.*
April	39.9	76.9	0.22	3.52
May	47.9	88.0	Trace.	6.28
June	56.4	71.7	.22	6.64
July	60.7	47.1	5.71	1.72
August	61.4	49.0	2.76	2.67
September	57.0	45.0	3.47	3.08
October[2]	44.9	60.3	2.68	2.52

[1] From free water surface. [2] First killing frost, October 3.

Total precipitation April 1 to June 30, 0.44 inch; July 1 to October 31, 14.62 inches.

OPERATIONS.

STOCK.

All of the stock used in this experiment has been grown at least one year in the nursery at Fort Valley. Only selected plants with good root systems were planted; the inferior ones were either discarded or placed in the transplant beds for another year. The plants were shaded during the process of lifting and were immediately placed in bundles of 15 to 20 packed in wet moss and burlap, in which condition they were carried to the field and planted. The roots were uniformly of a branching character with a mass of fine laterals. Practically all of the 1–1–1 and 2–1 stock had good root systems; but many of the 1–1 stock were inferior and had to be culled. Of the selected stock planted the 1–1–1 and 2–1 plants had a deeper and more spreading root system than the 1–1 plants. The following classes of stock were planted:

1–1, entirely home grown.
1–1, one-year seedlings from Fort Bayard Nursery transplanted in Fort Valley Nursery.
2–1, two-year seedlings from Nebraska Nursery transplanted in Fort Valley Nursery.
1–1–1, 1–1 stock from Fort Bayard Nursery transplanted in Fort Valley Nursery.

On account of the variety of stock and the small amount of each class available the desired uniformity of number in the different divisions of the experiment could not be maintained.

PREPARATION OF PLANTING HOLES.

1. Spots 18 inches in diameter spaded up to a depth of 1 foot in the fall of 1910 in order to absorb and hold moisture. The large rocks were removed and the surface of each spot was left about 2 inches below the surrounding level. Cost of preparation about $3.50 per 100.

2. Holes 18 inches in diameter and 12 inches deep dug in the fall of 1910 and left open over winter; filled in as soon as the soil began to dry in the spring in order to prevent hardening. Cost of preparation about $3.50 per 100.

3. Holes about 8 inches in diameter and 8 to 10 inches deep dug with spade and mattock at the time of planting.

The number of plants of each kind set under each method is given in the table under "Results."

Planting.—The dates of planting were: Area A, March 31 to April 1 and April 11; area B, April 7.

The mound or cone method of planting was used wherever the nature of the root would permit. Most of the 2–1 and 1–1–1 stock

was set by the mound method, and most of the 1–1 stock by the side-hole method. In every case the roots were spread out as well as possible and the soil was packed firmly in the entire hole or spot, but leaving a mulch of about 2 inches of loose soil on top.

The soil was fully saturated at the time of planting, and in some places it was even too wet to work well. Where the soil was so wet as to be in danger of becoming hard in drying, the surface was broken with a hoe after it had dried sufficiently to become crumbly. On April 25 the soil immediately around all of the plants was raked in order to break the crust which had formed as the result of a shower after planting.

TABLE 2.—*Soil moisture during the dry season.*

Method.	Area A.		Area B.
	Soil moisture.		Soil moisture, June 13.
	Apr. 27.	June 14.	
	Per cent.	*Per cent.*	*Per cent.*
Spots spaded 1910	23.0	18.85	5.30
Holes dug 1910, left open over winter	21.6	19.50	.....
Holes dug in spring, 1911, at time of planting	21.3	16.76	4.82

Each figure represents the average of 8 samples taken at a depth of 4 to 10 inches. All percentages are based upon dry weight of soil.

Examinations on area A during the summer showed that a number of plants were being killed by a "grub" eating the roots. The whole root is devoured up to within 2 inches of the root collar, with the result that the top of the plant dries up in a short time. Counts at the close of the season showed that 9.21 per cent of the plants on the area had been killed by this grub.

RESULTS.

TABLE 3.—*Area A, Fort Valley—Percentage of plants growing Oct. 6, 1911.*

Stock and method.	Number planted.	Growing Oct. 6.
		Per cent.
2–1 stock in spots prepared 1910	23	95.7
2–1 stock in holes dug at time of planting	23	91.3
1–1–1 in spots prepared 1910	42	92.9
2–1 stock in spots prepared 1910	78	92.2
1–1[1] stock in spots prepared 1910	106	90.7
1–1[1] stock in holes open over winter	120	85.8
Total	[2] 369	[3] 89.7

[1] Seedlings shipped from Fort Bayard, transplanted in nursery at Fort Valley.
[2] 23 plants in table used twice for comparison.
[3] 9.21 per cent of the loss is attributed to a grub which destroyed the roots.

TABLE 4.—*Area B, Flagstaff—Percentage of plants growing Oct. 4, 1911.*

Stock and method.	Number planted.	Growing Oct. 4.
		Per cent.
1–1 stock in spots prepared 1910	192	83.9
1–1 [1] stock in holes dug at time of planting	79	76.0

[1] Entirely home grown.

As stated under operations, 9 per cent of the transplants on area A at Fort Valley were killed by a grub eating the roots. Out of 369 transplants only 3, or less than 1 per cent, died from natural causes. An examination on December 15 found all the plants looking well. On account of the lateness of the snows this fall, it is possible that some damage will result from the cold, dry winds. Two plants dug on November 21 showed excellent root growth, which would indicate that the plants are practically safe from ordinary droughts.

CONCLUSIONS.

The important fact demonstrated by this experiment is that western yellow pine can be planted successfully in this region. The success is attributed almost entirely to the quality of the stock. Heretofore the stock used has not had a good root system, and since it has been shipped in, many of the plants probably suffered in transit. The plants used this year had fine root systems with an abundance of feeders, which enabled the plants to establish themselves early in the spring while the soil was moist. Our soil is usually in excellent condition early in the spring, and therefore it is firmly believed that if good vigorous stock is properly planted at this time of the year success is assured.

The meteorological records show that this has been an unusually wet year; but the excess of rain did not come until after July 1. The critical period is from April to July. During this period very little rain falls, but after July 1 to 15 there is usually an abundance of rain. The total precipitation at Fort Valley from April 1 to July 1, 1911, was 0.49 inch, while for the same period in 1910 it was 1 inch. The summer rains began two weeks earlier in 1911 than in 1910, but the spring season also began correspondingly earlier in 1911. In former years practically all of the loss has occurred before June 15, so that even if the rain had begun as early as this year no benefit would have resulted. It may therefore be assumed that this year's success is not due to a favorable season and that equally good results can be obtained in other normal years.

Because of the uniformly good results in the planting at Fort Valley (less than 1 per cent died from natural causes) no conclusion

can be drawn in regard to the respective merits of the various classes of stock and the different methods of preparing the planting holes.

The results on area near Flagstaff show 7.9 per cent more growing plants in the spaded spots than where no previous preparation was given; but, considering the cost ($2 to $3 per 100) of preparing spots or wide holes in advance of planting in addition to the cost of ordinary planting, this practice does not seem warranted under ordinary conditions.

The smallness of the effect of fall preparation of spots and wide holes upon the conservation of moisture is rather surprising in view of the recognized value of cultivation in this regard. As shown by the soil samples, Table 2, the spots having no cultivation in advance of planting have an average moisture content of less than 2 per cent below that of the cultivated spots or holes left open during the winter. Apparently, on account of the small extent of the area cultivated, the effect is neutralized by the surrounding drier soil absorbing the excess moisture. Plots 4 by 12 feet used as seed beds show a moisture content from 10 to 15 per cent above that of virgin soil.

The superiority of planting at Fort Valley (area A) over that near Flagstaff (area B) is attributed mainly to greater soil moisture, as shown by Table 2. There was no damage by grubs on area B. The soil on area A, and especially the subsoil, is of an adobe character, which holds the moisture better than the lighter soil on area B. The practical difference, however, is probably not so great as the figures would indicate, because the percentage of nonavailable moisture in the heavier soil is undoubtedly greater than in the lighter soil.

SEED SPOTTING DOUGLAS FIR UNDER ASPEN.

FORT VALLEY EXPERIMENT STATION.

NORMAN W. SCHERER, *Forest Guard.*

OBJECT.

To determine (1) whether Douglas fir can be grown successfully in this region by the seed-spot method; (2) the advantage, if any, of preparing the spots in advance of seeding; and (3) the best time to sow, whether in the spring or at the beginning of the rainy season in July.

LOCATION.

Transition type; altitude 8,700 feet.

OPERATIONS.

TIME AND METHOD.

1. *Spring seeding—April 15.*—The soil was in excellent condition, being practically saturated with moisture. Patches of snow lay on the area. A few small showers fell during the first two weeks after the seeding, but during May and June there was practically no precipitation.

(*a*) Spots prepared in the fall of 1910. Each spot was about 18 inches in diameter, and the soil was loosened with a spade and crowbar to a depth of 1 foot, all large rocks and roots being removed.

(*b*) Spots prepared at the time of seeding. The spots were 18 inches in diameter, but cultivated to a depth of only 4 to 6 inches.

2. *Summer seeding—July 7 to 15.*—The soil was well soaked by rains which had fallen during the week prior to the seeding. There was an abundance of rain during the whole season after the seeding.

All of the spots were prepared at the time of sowing, as in 1 *b*.

SEEDING.

The seed used in both spring and summer sowing was collected on the Pecos National Forest in 1909. It was kept in tight boxes in a fairly cool storeroom at Fort Valley. The cutting test in July was 76 per cent.

The method of sowing the seed was uniform in the whole experiment. The soil was firmed with the back of a hoe or rake. From 15 to 20 seeds were scattered in each spot, and covered with about

one-fourth inch of fine soil. All spots were spaced 6 by 6 feet, excepting where trees, rocks, etc., made wider spacing necessary.

PROTECTION.

Poisoned wheat was scattered on and around the area a week before and at the time of each sowing.

Protective screens were placed over 14 spots of the summer sowing and 5 each of the fall and spring prepared spots of the spring sowing.

COST.

Cost per acre for the area where the spots were prepared at the time of seeding, including seed and labor, was $11. This does not include time consumed in going to and from the area, a distance of 5 miles.

The cost per acre for the area on which the spots were prepared in the fall upon the same basis as above is about $34.

RESULTS.

Sample counts on December 1 gave the following results:

TABLE 1.—*Results of seed sowing in 1911.*

Season and method.	Spots containing seedlings.		Average number of seedlings per spot.		Total number of spots seeded.
	Screened.	Unscreened.	Screened.	Unscreened.	
Spring seeding:	*Per cent.*	*Per cent.*			
Spots prepared fall 1910	75.0	20.3	6.2	1.4	117
Spots prepared spring 1911	33.3	21.7	12.0	1.5	93
Summer seeding, spots prepared summer 1911	82.4	20.0	6.5	1.4	663

Considerable numbers have already been heaved out of the ground by freezing. Those which have not been heaved out are as a rule looking sturdy and vigorous.

CONCLUSIONS.

Later in the fall there seemed to be no appreciable difference in the results of the different methods. There is a decided difference in favor of fall prepared spots where screened, but the results can not be regarded as conclusive on account of the small number of spots screened.

The decided superiority of the screened spots over the unscreened spots shows that the damage by animals is very great. Mice and chipmunks are known to be active seed destroyers; other rodents and birds may also take a part. If the damage by animals could be eliminated, good results might be expected. The use of screens on a large scale is impracticable on account of the high cost, while poisoning seems to be ineffective.

METHODS AND SEASONS FOR DOUGLAS FIR REFORESTATION.

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

The purpose of this experiment, started in the winter of 1909–10, is to determine the best method and season for Douglas fir reforestation in the front range of the Rocky Mountains. The conclusion is to be based on the cost of securing a reasonable stand of seedlings. For purposes of comparison the cost of each seedling will be taken.

LOCATION.

The experiment has been carried on at the Fremont Experiment Station, at an altitude of 9,100 feet, which is approximately at the lower edge of the Douglas-fir type. The site chosen is a flat ridge top, having an almost imperceptible slope to the south and having a loamy gravel soil formed by the decomposition of granite and containing very little silt. The principal soil cover is bearberry (*Arctostaphylos uva-ursi*) with scattered bunches of grass. The site is a difficult one for Douglas fir, since at this elevation the species is found on the upper portions of north slopes. However, the presence of mature Douglas fir, yellow pine, and limber pine on the site, together with seedlings of all of these species, indicate that Douglas fir growth is not here impossible. It is one of the sites which might be covered by either yellow pine or Douglas fir, but would not reproduce to Douglas fir naturally, except after a long period.

OPERATIONS.

The operations in this experiment comprise a series of tests in which sowing by four different methods and planting of nursery stock are each executed in the spring, summer, and fall, and in addition broadcasting without preparation (on snow) is executed in the winter. The four methods of sowing were (1) broadcasting without preparation of the soil, (2) broadcasting after harrowing, (3) corn-planter sowing, and (4) sowing in prepared seed spots, the spots being approximately a foot in diameter and loosened to a depth of 3 inches.

In each of these operations at each season a plot 40 by 40 feet, or approximately one-twenty-fifth acre, was used.

Broadcast sowing was done at the rate of five good seeds per square foot; corn-planter sowing, approximately 10 good seeds per spot;

FIG. 1.—SCREENS FOR PROTECTING SEED SPOTS AGAINST BIRDS AND RODENTS. DOUGLAS FIR SEED SPOTS UNDER ASPEN. FORT VALLEY EXPERIMENT STATION.

FIG. 2.—SITE ON WHICH THE BEST METHODS AND SEASONS FOR DOUGLAS FIR REFORESTATION WERE DETERMINED AT THE FREMONT EXPERIMENT STATION.

Plot in foreground shows early results of summer broadcasting on harrowed ground, each stake marking a seedling.

and seed-spot sowing, 20 good seeds per spot. Seed used was of local collection and had a germinative capacity of 72 per cent.

RESULTS.

The results of the various operations, beginning with broadcasting on snow in the winter of 1909–10 and ending with sowing and planting in the fall of 1910, are shown in Table 1:

TABLE 1.—*Results of various methods of sowing and planting.*

Method.	Season.	Total germination.	Seedlings surviving.		Total germination surviving, fall, 1911.
			Fall, 1910.	Fall, 1911.	
					Per cent.
Broadcast, no soil preparation	Winter	9	.....	2	22
	Spring	42	13	2	5
	Summer	59	16	9	15
	Fall	10	.....	10	100
Broadcast, harrowed ground	Spring	549	307	34	8
	Summer	805	395	57	7
Corn-planter sowing	Spring	56	19	.....	.....
	Summer	45	44	.....	.....
Prepared seed spots	Spring	209	69	22	10
	Summer	186	133	8	4
	Fall	52	.....	47	90
Planting direct from nursery	Spring	.....	35	27	.....
	Summer	.....	2	0	.....
	Fall	.....	70	18	.....
Planting, foreign stock	Spring	.....	17	16	.....
Planting, hardened stock [1]	Fall	.....	88	56	.....

[1] Held in transplant bed in immediate vicinity during preceding summer and not watered.

CONCLUSIONS.

On the facts indicated by the figures in Table 1 the following observations may be made:

1. Broadcasting of seed on unprepared ground was almost a complete failure, although on account of the less heavy soil cover it produced better results than were secured in the yellow-pine experiment carried on at the same time. Slightly better germination and survival was obtained from the summer sowing, which was immediately followed by frequent rains, than from the sowing at other seasons.

2. Broadcasting on harrowed ground (the harrowing in a large measure uprooted the bearberry) induced good germination, both after the spring and summer sowings. The summer sowing was slightly in the lead. The seedlings of both sowings, however, appeared to be very tender, so that the loss during the first winter was nearly 90 per cent. This may be explained in part by the lack of snow covering on this site and in part by the heaving out of seedlings when the ground thawed the following spring.

3. Although the counts of seedlings resulting from corn-planter sowing could not be made in the fall of 1911, it was evident at the end of the first season that this method had produced very meager results. As with the broadcasting on unprepared ground, the results, however, are slightly better than were secured with yellow pine.

This seems to furnish perfectly clear evidence that the failure of these primitive methods is due to the vigorous competition of native vegetation.

4. Spring seed-spot sowing germinated slightly better than summer sowing, and a greater proportion of the seedlings survived until the end of the second year. The number of seedlings surviving in the fall of 1911 from the fall sowing should be compared with the number surviving in 1910 from the spring and summer sowings, and it is found on this basis that fall sowing is not desirable. The great loss of seedlings during the first winter is explained on the same basis as the loss in broadcasted plots.

5. Spring planting of local stock is found to be preferable to summer or fall planting. The foreign stock was in bad condition when received, but under the circumstances made a good showing. In the fall planting the stock which had been in the local nursery during the summer and which had not been watered made a much better showing than trees of the same class which had been in a larger nursery and were watered during the summer. Summer planting has no justification in the Douglas-fir type.

Selecting from each method the season's operations which produced the best results and thus comparing directly the best which can be obtained by any method, the cost of producing trees is as follows:

Table 2.—*Summary of costs of trees under each method.*

Season and method.	Thrifty trees, fall, 1911.	Total cost.	Cost of each surviving tree.
Summer:			
Broadcast, unprepared	13	$0.62	$0.0477
Broadcast, harrowed	63	1.11	.0176
Spring, seed spots	22	1.09	.0495
Fall planting (not watered)	28	.855	.0305

While the number of trees involved in the calculations above is too small for reliable conclusions, it appears fairly plain that where this method is possible summer broadcasting on harrowed ground is the cheapest method for obtaining a stand. However, this method produced only about 1,600 trees per acre when seed was used extravagantly, and it is doubtful if the results justify the expense. In view of this fact much the same methods are being employed in a duplication of this experiment on a site which belongs typically to Douglas fir. The experiment has also been duplicated in 1911 on the Sopris Forest, where climatic conditions in the Douglas-fir type are different, and is being similarly duplicated in 1912 on the Durango Forest, where the distinct summer rainy season will undoubtedly produce results of a very different character.

SITE STUDIES.

YELLOW-PINE HABITAT EXTENSION.

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

The purpose of this experiment, begun at the Fremont Station in 1911, is to determine the possibility of artificially extending the natural habitat of yellow pine downward into the zone naturally occupied by piñon, juniper, and chaparral oaks, which are relatively worthless species from the commercial standpoint.

LOCATION.

The site of the experiment is a steep south slope at 7,000 feet elevation, having a loose, coarse gravel surface soil, underlaid with loamy gravel. Clumps of oak (*Q. gambellii*), yuccas, and occasional bunches of grass comprise the soil cover. Piñon is found both above and below the site.

OPERATIONS.

In the spring of 1910 one 40 by 40 foot plot was sown in 100 seed spots with seed from the Coconino National Forest, in Arizona, and one plot planted with 100 1–1 stock from Fort Bayard Nursery. In the fall a similar plot was planted with 2–1 stock from the same nursery. The seed sowing was an absolute failure, on account of the rigorous conditions of the site, and the planting was virtually a failure, owing largely to the poor quality of the stock used.

In the spring of 1911 two plots were planted with the following stock:

TABLE 1.—*Stock planted, spring, 1911.*

Source of stock.	Source of seed.	Age.	Tops.	Roots.
Fort Bayard	Nebraska	2–1	2 to 6 inches, stocky...	6 to 12 inches, few fibrous.
Monument	Pike National Forest..	2–2	6 to 8 inches, stocky...	8 to 12 inches, many fibrous.

One hundred plants from each nursery were used, spaced 4 by 4 feet, and the cone method employed in setting. The ground was very moist from recent snowstorms at the time of planting, and the plants were given a very favorable start.

From the results of other experiments Monument 2–2 stock is felt to be too large to handle with the greatest success, and accordingly the Fort Bayard stock had the advantage of age. This was about counterbalanced, however, by the better root systems of the Monument stock, as shown in Table 1.

RESULTS.

Table 2 shows the number of plants living in each plot and the soil moisture at 6-inch depth at the various seasons:

Table 2.—*Results of 1911 planting.*

Source of stock.	Living plants, 1911.			Soil moisture 6-inch depth.	
	Spring.	Summer.	Fall.	Spring.	Summer.
				Per cent.	*Per cent.*
Fort Bayard	93	52	40	5.75	1.97
Monument	97	53	48	7.29	1.67

The deficiency of soil moisture in the summer at this site is very noticeable, and is especially great in the plot which had the best moisture in the spring.

Several factors besides drought have greatly increased the death rate in each plot and have badly injured the plants still living. Among these are trampling by men and horses, gnawing by rabbits, and burying by gravel.

The Fort Bayard stock planted in the spring of 1911 appears stronger and has made greater growth than the Monument stock, though a smaller percentage of it survived.

The growing season of 1911 was marked by low temperatures and light precipitation, while the preceding winter was marked by an excess of both precipitation and heat. The figures for Colorado Springs, located 8 miles distant and somewhat lower, are shown in Table 3:

Table 3.—*Departure from normal temperature and precipitation, Colorado Springs, 1911.*

Month.	Precipitation.	Temperature.
	Inches.	° *F.*
January	−0.20	+9.0
February	+1.49	−2.5
March	− .32	+4.3
April	+1.01	−6.2
Excess accumulated since Jan. 1	1.98	4.6
May	−1.75	+1.0
June	−1.15	+2.2
July	− .67	−2.5
August	−1.05	−1.4
September	+ .60	− .8
Deficiency accumulated during growing season	4.02	1.5

CONCLUSIONS.

From results so far obtained, the following conclusions are drawn:

1. Sowing seed, and planting any but the very hardiest stock on such a site, are futile.

2. Hardy, well-developed transplants, preferably 3 years old, can be planted in the piñon-juniper type, with good chances of success. This conclusion is based on results obtained during a season very deficient in precipitation. The greatest care was exercised in handling the stock and in setting every plant.

3. On account of the greater success which may be attained with less expense, yellow pine planting should be confined to the higher and moister sites until the art of treating these low, dry sites has been exhaustively developed.

4. On account of the variable age and condition of stock used, no conclusions can be drawn in relation to the effect of source of stock on success. However, the results of other experiments lead to the conclusion that—other factors being equal—Monument stock is superior to Fort Bayard stock for use at any site in the Pikes Peak region. This phase of the experiment is being developed at the present time, since it has been thought that, for these dry and warm sites, stock of southerly origin would be best adapted.

DOUGLAS-FIR HABITAT EXTENSION.

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

The purpose of the experiment is to determine whether Douglas fir can be successfully grown at altitudes above its natural zone, in a second-quality Engelmann spruce site, where the original stand has been destroyed by fire. Douglas fir is considered the more advantageous species for this type, on account of its greater economic value, provided its growth is equal to that of spruce.

LOCATION.

The site chosen for the experiment is a low rounded ridge in the Engelmann spruce-limber pine type, at an elevation of 10,250 feet, with a slope of 5 to 10 per cent to the east. The soil is a loamy gravel, and the ground cover scattered bunches of grass, with many old logs. A few young limber pine and aspen occur on the plots. The ground appears to have been very severely burned within the last 20 years.

OPERATION.

In the spring of 1910, one 40 by 40 foot plot was sown with Douglas-fir seed in 100 well-prepared seed spots, and a similar plot planted with 100 plants. This work was repeated in the fall of 1910.

The seed used was collected on the Colorado National Forest in 1908, contained 48,810 seeds per pound, and showed a germinative capacity of 13 per cent by local greenhouse tests. It was sown at the rate of 20 good seeds per spot, based on a cutting test of 48 per cent.

The stock used in the spring was 3-year seedlings from Bear Creek Nursery; that used in the fall was the same, after a summer in the transplant beds, 50 plants having been held at Monument Nursery, where they were watered, and 50 plants in the local nursery, where they received no artificial watering. The stock used in the spring was undoubtedly too small and tender, while that used in the fall was much sturdier, though still small.

RESULTS.

Table 1 shows the number of living plants in the fall of 1910 and in the spring, summer, and fall of 1911, together with the total ger-

mination, the 1911 germination, and the ratio between the total germination and the number of good seed sown in the seed-spot plots:

TABLE 1.—*Results of sowing and planting.*

Season of operation.	Method.	Living plants.				Germination.		
		Fall, 1910.	June, 1911.	July, 1911.	Oct., 1911.	1911.	Total. Actual.	Total. Of possible.
								Per ct.[1]
Spring	Sowing	77	7	29	30	42	212	39.2
Do	Planting	40	16	24	[2] 27	.....	.....	.....
Fall	Sowing	.....	28	114	127	142	142	26.4
Do	Planting	96	26	48	[2] 49	.....	.....	.....

[1] "Germination of possible" is figured on the basis of the number of good seed sown, as shown by greenhouse germination tests, while the sowing was actually done on the basis of cutting test previously made.
[2] Many of the plants which appeared dead or failing at the time of the spring counts had started growth in the fall from side buds near the surface of the ground.

It is to be seen that the field germination was quite good. Little or no trouble was experienced from the destruction of seed by birds and rodents while they were in the ground, but many plants were killed or injured as they came through the ground.

In the plot sown in the spring of 1910, the winter death rate was 91 per cent, largely caused by heaving and drying out. Of the 30 plants surviving in the fall of 1911, only 3 were of 1910 germination.

Of the stock planted in the fall of 1910, that which had been in the local transplant beds without water showed a percentage of thrifty plants of 54 per cent, as against 44 per cent for stock which had been in the watered transplant beds at Monument Nursery.

Table 2 compares the results obtained in the seed spot and planting tests of this experiment with those of similar tests carried on at the same time at an elevation of 9,175 feet.

The stock used in the two places was from the same lots. The seed used at the lower elevation was of much better quality, but the germination is in both cases calculated on the basis of number of good seed sown.

TABLE 2.—*Comparative results at elevations of 9,175 and 10,250 feet.*

Method.	Season.	Total germination of good seed sown.		Survivals, fall, 1911.			
		9,175 feet.	10,250 feet.	Actual. 9,175 feet.	Actual. 10,250 feet.	Of total germination. 9,175 feet.	Of total germination. 10,250 feet.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
Sowing	Spring	14.15	39.20	22	30	10.5	14.15
Do	Fall	3.52	26.4	47	49	90.4	80.3
Planting	Spring	.....	.....	27	27	.....	.....
Do	Fall	.....	.....	37	49	.....	.....

It is evident that, despite the poorer seed used, a larger actual germination and a much larger percentage of germination was obtained at the high altitude in sowing operations, as well as a larger number of survivals in the case of both sowing and planting operations. This is probably, in a large measure, due to the fact that the site of the low elevation tests was drier than the high site. In fact it is a little too dry to be considered typical Douglas-fir ground.

Table 3 shows the soil moisture conditions of the various plots involved in this experiment during the season of 1911.

Table 3.—*Moisture condition of various plots during 1911.*

Plot used for—		Soil moisture.		
Season.	Method.	June, 1911.	July, 1911.	Oct., 1911.
		Per cent.	*Per cent.*	*Per cent.*
Spring	Sowing	4.56	12.17	5.03
Do	Planting	5.67	12.35	5.86
Fall	Sowing	7.50	9.33	6.02
Do	Planting	6.37	8.11	5.11
Average		6.02	10.49	5.50

The above table shows that the soil of the plots used in the spring planting and sowing was drier in June and October than that of the plots used in the fall, while the opposite is true in July.

A comparison of the figures for 1910 and 1911 show that the soil was markedly moister in 1911 than in 1910.

The site used for this experiment is much moister than that used for Douglas-fir sowing and planting at the lower elevation. There the average moisture percentage in July was 8.80, and in October 4.67.

CONCLUSIONS.

1. As far as conclusions can be based on the results after only two seasons, it is evident that Douglas fir can be successfully started in the Engelmann spruce-limber pine type. When good seed and sturdier stock are employed, the results will probably be much better than those obtained so far in the conduct of this experiment. They already compare favorably with results at lower elevations, but the final comparison must be on the basis of growth.

2. No conclusions are as yet possible as to the relative value of fall and spring sowing operations at high altitudes, because the fall sowing has had only one growing season in which to germinate, and the seedlings have not as yet passed their first winter.

3. No conclusions are possible as to the relative merits of planting nursery stock in the fall and spring at high altitudes, owing to the fact that 3-year seedlings were planted in the spring, while 3–1 stock was used in the fall.

4. It is felt that fall work, both in seed sowing and in planting operations will be more successful at high altitudes than at lower ones on account of the greater protection given the seeds and plants by frozen ground and the blanket of snow throughout the trying winter season.

5. Stock which has been hardened off by the withdrawal of artificial water in the transplant beds is much preferable to that which, while larger, is weaker because of pampering in the nursery.

STUDIES OF BRUSH DISPOSAL.

BRUSH DISPOSAL.

FORT VALLEY EXPERIMENT STATION.

G. A. Pearson, *Forest Examiner.*

OBJECT.

To determine the effects upon reproduction of scattering the brush after logging in a western yellow-pine stand.

LOCATION.

Greenlaw sale area, logged 1908; area, 126 acres.

OPERATIONS.

The area was laid off and a preliminary study made in 1908. A report upon this study entitled "The Effect of Scattering the Brush, after Logging, upon the Reproduction of Western Yellow Pine" was submitted in February, 1909.

The area was fenced in the spring of 1909. Fire lines were burned in the winter of 1908–9 and plowed in the spring of 1911.

RESULTS.

In the report upon the study in 1908 the following conclusions are drawn:

A brush cover exercises a moderating influence upon temperature, especially at night, when it may be instrumental in protecting seedlings from frost. Measurements show the temperature on clear, still nights to be as much as 7.9° F. higher under the brush than in the open. Observations also show that when the temperature dropped to 15° early in October, killing the majority of the first-year seedlings on exposed plots, adjoining brush-covered plots suffered no injury.

It was found from measurements that a brush cover is effective in conserving soil moisture; this effect is especially noticeable in the surface layers.

The cost of scattering the brush is approximately the same as the cost of piling it.

SUBSEQUENT STUDIES.

The cutting was done in a good seed year, with the result that an abundance of seedlings sprang up during the summer rainy season of 1909. As is the case in broadcast sowing, there was a considerable loss even during the rainy season from short periods of drought and to some extent from damping off under the brush. Although this agency was not discovered at that time, it is probable that birds destroyed many seedlings. The greatest loss came in October and November, after the soil began to dry out in the upper layers. No serious damage from frost was observed in 1909 as in the preceding fall.

Seedling counts on 5 by 10 foot sample plots in 1909, 1910, and 1911 gave results as shown in the tables below. All of the seedlings considered started in 1909. There has been practically no germination since.

TABLE 1.—*Number of seedlings on plot.*

Character of plot.	July, 1909.	Nov. 20, 1909.	July 13, 1910.
Open		2	2
Do		2	0
Do		19	9
Do		5	0
Average		7	2.75
Brush covered		6	1
Do		1	0
Do		2	0
Do		0	0
Average		2.25	0.25

Because of the changed conditions produced by removing and replacing the brush each time a count was made, a new series of plots of the same size were laid off in 1911. Ten of these plots were counted on September 9, with the following results:

TABLE 2.—*Number of seedlings per plot Sept. 9, 1911.*

Open.	Brush covered.
2	0
1	2
0	0
0	0
2	0
1.00	0.4

All of the seedlings in the above tables started in July and August, 1909. There has been but little seed since 1908.

The results of soil samples taken through the season of 1909 on open and brush covered areas are given in the table below:

TABLE 3.—*Percentage of soil moisture.*

Date.	Open-area depth (inches).			Brush-covered depth (inches).		
	0–1	0–4	4–8	0–1	0–4	4–8
1909.						
May 1 [1]	1.1	7.1	.....	[2] 5.3 19.4	14.6	....
May 29 [3]	1.1	2.9	10.8	2.5	9.6	14.2
July 3 [4]	1.1	5.4	8.7	1.6	6.5	11.7
Aug. 5 [5]	.....	10.0	14.2	.....	13.3	16.8
Sept. 4 [5]	17.3	21.0	.....	22.7	21.2	.....
Oct. 4 [6]	1.5	10.9	.....	11.0	16.4	.....
Nov. 6 [6]	.....	3.6	9.6	.....	6.9	10.6
Average	4.7	8.7	10.8	8.6	12.6	13.3

[1] Beginning of dry season
[2] Under old leaf litter.
[3] Dry season.
[4] Height of dry season, just before beginning of summer rain.
[5] Rainy season.
[6] Fall dry season.

As is usually the case in this region, germination did not take place until the arrival of the summer rains in July. The explanation for this is found in the soil moisture. As shown by the preceding table, the surface layer to a depth of 1 inch was dry as early as May 1. From the time the snows melt in April until July there is practically no rain, with the result that the surface layers of the soil dry out very rapidly. The moisture records show that the presence of a brush cover retards the loss of soil moisture very considerably, but apparently the effect ordinarily is not sufficient to enable germination to take place in the spring.

A comparison of the brush-covered and open plots show that the death rate is much greater in the former. There are several explanations for this: First, many seedlings starting in the duff do not succeed in sending their roots far enough into the mineral soil to withstand drought and heaving. Secondly, the brush harbors insects, many of which will injure seedlings. During the summer of 1909 there was some damping off in the brush, but it is not believed that in ordinary years this disease will prove very troublesome.

The first named of the above factors is probably the most important. The presence of brush and duff hinders many seeds from reaching the ground, and many of those which do reach the ground do not reach the mineral soil. Examinations during the past season indicate that the brush was scattered too closely, on the whole, the needles falling from the branches having formed a mat which seeds can not penetrate. Frequently, however, there occur small bare spots in the brush which have the advantage of an exposed soil and the protection of surrounding brush.

CONCLUSIONS.

While in the present experiment the brush cover seems to have acted as a detriment rather than a benefit to reproduction, the final result may prove to be different. Although the brush during the first few years keeps the seed from reaching the soil, the disadvantage may be offset in later years by the benefit which the decayed vegetable matter will have upon the soil.

Much depends upon the density of the brush and the period which elapses between the scattering of the brush and the first good seed year. If a seed crop should not occur within five years a fairly dense brush cover is permissible, but if a seed crop comes in one or two years the cover must be sufficiently open to permit the seeds reaching the soil. Ordinarily, the latter condition is recommended. For economic reasons, the branches should be cut as large as they can conveniently be handled, but they should be distributed so as to leave alternate bare spots or strips from 6 to 12 inches wide between the branches. While the seed falling directly upon the brush will largely be lost, that which falls on the small open spots will have access to the mineral soil and at the same time will be protected by brush on all sides.

STUDIES OF ANIMALS INJURIOUS TO FORESTATION.

METHODS OF COMBATING SEED-DESTROYING ANIMALS.

FORT VALLEY EXPERIMENT STATION.

G. A. Pearson, *Forest Examiner.*

OBJECT.

On account of the destruction of seed and young seedlings by rodents and to a less extent by birds, direct seeding has been a total failure throughout the district in almost every instance where it has been attempted. So persistent and uniform have been the failures due to this cause that it is the concensus of opinion throughout the district that direct seeding is almost hopeless, unless the rodent evil can be eliminated.

LOCATION.

Sowing areas on the Coconino and Gila National Forests have been given special attention, but observations cover almost every forest in the district.

OPERATIONS.

Three general methods have been employed as follows: (1) Special treatment of the seed before sowing, (2) poisoning the animals, and (3) the use of protective screens on seed spots.

1. TREATMENT OF SEED.

In 1909 and 1910 most of the western yellow pine and Jeffrey pine seed sown at the Fort Valley Station was coated with red lead before sowing. Approximately 20 acres were sown broadcast in 1-acre plots at different times on the Coconino National Forest with seed treated in this manner. The treatment was also used at the Fort Bayard and Gallinas planting stations.

2. POISONING.

Several poisoned baits were tried in 1909, 1910, and 1911. The one mostly used is prepared according to the following formula prescribed by the Biological Survey:

Strychnine sulphate	1 ounce.
Saccharine	Same volume as strychnine.
Laundry starch	1 heaping tablespoonful.
Water	1 pint.
Wheat	16 quarts.

Put starch in water, heat until thick, add strychnine (pulverized) and saccharine, and stir well. Pour this solution over wheat and stir until every kernel is coated.

Poisoned barley, oatmeal, and green alfalfa have also been used at the Fort Valley Station.

The baits were distributed several times before and immediately after sowing, placing about one-half tablespoonful in a spot at intervals of 20 to 30 feet, usually under logs or stones. On one area in particular at the Fort Valley Station the poisoning was very thorough and systematic. Poisoned wheat was distributed over and for 40 to 80 rods around this area every two or three weeks from March 20 to August 1. Barley, oatmeal, and green alfalfa were also used. During a portion of the season the work was done under the personal direction of a member of the Biological Survey.

3. PROTECTIVE SCREENS.

The use of screens on seed spots was first practiced in the spring of 1911. The greatest difficulty in this method is to secure screens at a nominal cost. Two types have been tested. One is a wooden frame 4 inches high and 1 foot square, covered with $\frac{1}{2}$-inch mesh hardware cloth. The other is 8 inches square by 5 inches high, and is made entirely of wire. The cost of the former is $10.28 per hundred, and of the latter $22 per hundred. It is estimated that the all-wire screens would last 10 years and those with wooden frames 5 years.

Two hundred screens were used in connection with seed-spot experiments at the Fort Valley Station and 100 at the Fort Bayard Station in 1911.

RESULTS.

1. TREATMENT OF SEED.

This method was found to be wholly ineffective.

2. POISONING.

While this practice has been productive of beneficial results, it still leaves much to be desired. On the area where poisoning was continued throughout the spring and early summer seed spots sown in March remained untouched until July, but at this time, when germination began, rodent work became very much in evidence. From observation it is believed that the chipmunks and mice were pretty well exterminated on the area poisoned, but apparently others came in from the outside.

It seems probable that by distributing poison very systematically over a sufficiently large area rodents can be exterminated, but birds present a more difficult problem. Observations at Fort Valley in

1911 indicate that the junco (*Junco dorsalis*) did fully as much damage as rodents. This bird does not stop with eating the seeds, but cuts down tender seedlings for two weeks or more after germination. Seedlings just out of the ground, before the seed coat is shed, are especially susceptible, but they are not safe from the junco until they are at least two weeks old. Attempts to poison the junco with wheat failed because he would not touch a grain. The poisoning of birds is undesirable because of their beneficial action in other respects. Furthermore, such a measure would be impractical because of their migratory habits. It therefore appears that while poisoning might be made to prove effective against rodents, it is wholly ineffective against birds.

Further observations are needed to ascertain how generally the trouble from birds applies to the whole district.

3. PROTECTIVE SCREENS.

The effect of screens is shown by a comparison of results in screened and unscreened spots in the seed-spot sowings of the Fort Valley Station in 1911. The results by species are given in the following table:

TABLE 1.—*Result of seedling counts, screened and unscreened spots, at close of season 1911.*

Species.	Number of spots.		Percentage containing seedlings.		Number of seedlings per spot.[1]	
	Screen.	No screen.	Screen.	No screen.	Screen.	No screen.
Pinus ponderosa:						
Area A	15	896	73.3	18.8	6.4	2.2
Area B	26	779	57.7	.....	9.0	.....
Pinus jeffreyi	15	187	80.0	4.3	3.9	1.6
Pinus gerardiana[2]	6	106	16.6	.....	1.0	.....
Pinus austriaca:						
Area A	22	177	72.8	.6	4.1	2.0
Area B	11	76	73.0	.....	28.2	.....
Pseudotsuga taxifolia	24	849	82.4	20.0	6.5	1.4
Picea excelsa	15	533	53.3	4.0	2.1	1.0

[1] Only the spots containing seedlings considered. [2] Poor seed.

The results for the native species in the screened spots are considered satisfactory on the whole, thus proving the efficiency of the screens. The final results will now be determined mainly by climatic conditions. The number of seedlings per spot will probably be greatly reduced before the next summer rainy season occurs, but if two or three seedlings survive in each spot the results will be considered satisfactory.

CONCLUSIONS.

Treating seeds with red lead is ineffective. Poisoning might be made effective against rodents, but not against birds.

Screens are effective against both birds and rodents, but are impracticable at present on account of the cost. If all-wire screens could be obtained for 15 cents instead of the present price of 22 cents, the cost might be brought within practical limits. Assuming that such a screen would last 10 years, the cost for protection would be 1.5 cents per spot. Sowing 1,000 spots of western yellow pine per acre, the cost would be $15 for protection. Add to this the cost of seed and labor and the cost per acre would amount to from $20 to $25, depending upon the amount of cultivation given the spots. This would place the cost about on a par with planting. Since most of our western yellow-pine areas have some natural reproduction, and since this species makes good timber in an open stand, it is believed that the number of spots could be reduced to 500 or 600 per acre. This would bring the cost within reasonable limits.

INFLUENCE OF BIRDS AND RODENTS IN REFORESTATION.

FREMONT EXPERIMENT STATION.

WILLIAM D. HAYES, *Forest Assistant.*

OBJECT.

To determine to what extent the depredations of birds and rodents influence the success of direct seeding work in the yellow-pine type, the value of poisoning sowing areas, and the best methods and seasons for work in areas known to be especially infested with these animals.

LOCATION.

The site chosen for this experiment is in an open stand of yellow pine, with a southern aspect and a gradient of 15 to 20 per cent. The soil is a loamy gravel, bearing a heavy sod of grass, and occasional patches of bearberry (*Arctostaphylos*).

OPERATIONS.

The area was divided into two sections, only about 500 feet apart, and practically identical in every factor. One of these sections was poisoned by scattering wheat prepared by the "strychnine-saccharine-tallow" formula on an area of nearly 3 acres (15 times the area seeded) at the time of sowing, and one and two weeks previous, while the other section was entirely unprotected by poisoning.

The following sowing operations were performed in the fall of 1910, using one 40 by 40 foot plot in each test of yellow pine and Chilgoza pine (*P. gerardiana*). The latter species was chosen on account of its size and its known attractiveness to animals:

In poisoned area:

- 1 plot broadcasted after harrowing, seeds 5 per square foot.
- 1 plot, 100 seed spots, one-half of which were heavily mulched with available litter, 20 seeds per spot.

In unpoisoned area:

- 1 plot broadcasted after harrowing, 5 seeds per square foot.
- 1 plot, 100 seed spots, all mulched heavily with available litter, 20 seeds per spot.
- 1 plot, 100 seed spots, of which 75 were unprotected while 25 were immediately covered with wire screens, 20 seeds per spot.

The seed of Chilgoza pine was sown at half the rate given above as used for yellow pine on account of the limited supply available.

This work was repeated in the spring and summer of 1911, the work with Chilgoza pine being abandoned on account of the exhaustion of the supply of seed. No poisoning was done in connection

with the summer work through oversight of the man temporarily in charge of the station.

The screens used in protecting part of the seed spots in the unpoisoned area were 12 by 12 by 6 inches high, made of $\frac{1}{4}$-inch mesh hardware cloth, and cost 32 cents each. No indications were found of any depredations in spots thus protected.

The only visual evidences of the effect of poisoning were about seven or eight dead jays found on the ground in the fall and spring. The seed spots in the poisoned area were dug up continuously at all seasons, seemingly as much as, or more than, those in the unpoisoned area.

RESULTS.

Table 1 shows the results obtained from broadcasting yellow pine in the poisoned and unpoisoned areas:

TABLE 1.—*Results of broadcasting yellow pine after harrowing.*

Area.	Season.	Seedlings alive in—			Total germination.	
		June, 1911.	August, 1911.	October, 1911.	Actual.	Of possible.
						Per cent.
Poisoned	Fall, 1910					
Do	Spring, 1911		1,160		1,353	16.93
Do	Summer, 1911	(1)	(1)			
Unpoisoned	Fall, 1910		204		217	2.71
Do	Spring, 1911		1,323		1,360	17.00
Do	Summer, 1911	(1)	(1)			

[1] No counts made.

The results of broadcasting are characterized by heavy germination from spring sowing and little or no germination from fall sowing. The germination in the unpoisoned area exceeds that in the poisoned at both seasons. No counts were made in the summer-sown plots because of the lack of poisoning in connection with the work of that season.

Table 2 shows the results obtained from sowing yellow-pine seed in seed spots mulched with litter in the poisoned and unpoisoned areas:

TABLE 2.—*Results of sowing seed in mulched seed spots.*

Area.	Season.	Seedlings alive in—			Total germination.	
		June, 1911.	July, 1911.	October, 1911.	Actual.	Of possible.
						Per cent.
Poisoned	Fall, 1910	17	51	11	60	6.00
Do	Spring, 1911		534	111	541	54.10
Do	Summer, 1911			3	3	.30
Unpoisoned	Fall, 1910	115	133	66	212	10.60
Do	Spring, 1911		945	213	975	48.75
Do	Summer, 1911			23	25	1.25

The total germination from spring sowing again exceeds that from work in the fall; in spring, the heaviest germination comes from the poisoned area, while in fall work it comes from the unpoisoned area. The only comparison possible between work in the two areas is in the germination percentages because of the difference between the number of seed spots sown in the two areas by this method. This applies as well to Table 3.

Table 3 shows the results obtained from sowing yellow-pine seed in unmulched seed spots in the poisoned and unpoisoned areas:

TABLE 3.—*Results of sowing in unmulched seed spots.*

Area.	Season.	Seedlings alive in—			Total germination.	
		June.	July.	October.	Actual.	Of possible.
						Per cent.
Poisoned	Fall, 1910	2	10	5	12	1.20
Do	Spring, 1911	.....	533	152	541	54.10
Do	Summer, 1911	.....	(1)	(1)	.....	.....
Unpoisoned	Fall, 1910	33	37	21	68	4.55
Do	Spring, 1911	.....	544	97	561	37.40
Do	Summer, 1911	.....	.....	24	31	2.07

[1] None sown.

These results bring out again the heavier germination in the spring-sown plots, and the better relative results from fall sowing on unpoisoned ground, and from spring sowing in poisoned areas.

Table 4 shows the results obtained from sowing seed in seed spots absolutely protected by screens from depredations in the unpoisoned area:

TABLE 4.—*Results of sowing in screened seed spots.*

Season.	Seedlings alive in—			Total germination.	
	Spring, 1911.	Summer, 1911.	Fall, 1911.	Actual.	Of possible.
					Per cent.
Fall, 1910	133	78	56	181	36.2
Spring, 1911	.....	395	341	417	83.45
Summer, 1911	.....	.....	174	182	36.4

A comparison of the figures in Table 4 with those for the unpoisoned area in Table 3 shows the vastly heavier germination induced when absolute protection from birds and rodents is given. The germination averaged for the 3 seasons over 50 per cent in screened spots, while it was only about 14 per cent in the unscreened, unmulched plot. Since other factors were identical, these figures give a good measure of the actual damage done by birds and rodents in field-seed sowing.

Since no poisoned wheat was scattered in connection with the summer sowing operations, the figures resulting from that sowing will not be considered in any comparison of results obtained in the poisoned and unpoisoned areas.

Table 5 shows the average moisture conditions of all plots used in this experiment in the poisoned and unpoisoned areas, in the spring and summer of 1911:

TABLE 5.—*Comparison of soil moisture.*

Method.	Poisoned area.		Unpoisoned area.	
	Spring, 1911.	Summer, 1911.	Spring, 1911.	Summer, 1911.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Broadcast, prepared	8.79	9.14	8.19	9.30
Seed spots:				
Mulched	8.15	9.63	7.49	7.48
Unmulched	.....	.....	8.68	7.26

This table shows that the poisoned area averaged a trifle moister than the unpoisoned area, but not enough so to account for the different results obtained.

Table 6 summarizes the results obtained from sowing yellow-pine seed by the various methods in the poisoned and unpoisoned areas, the details of which are shown in Tables 1 to 6:

TABLE 6.—*Summary of results.*

Method.	Seasons.	Per cent of possible germination.	
		Poisoned area.	Unpoisoned area.
		Per cent.	*Per cent.*
Broadcast after harrowing	Fall and spring	8.47	9.85
Seed spots:			
Mulched	do	30.05	29.67
Unmulched	do	27.64	20.97
Do	Fall, spring, summer	.....	14.67
Screened	do	.....	52.02

Based on the figures given in Table 6, the following arrangement may be made of the various methods in order of the percentages of germination recorded:

1. Seed spots, screened, unpoisoned area.
2. Seed spots, mulched, poisoned area.
3. Seed spots, mulched, unpoisoned area.
4. Seed spots, unmulched, poisoned area.
5. Seed spots, unmulched, unpoisoned area.
6. Broadcast, harrowed, unpoisoned area.
7. Broadcast, harrowed, poisoned area.

Assuming that the germination is in each case indicative of the damage by birds and rodents, i. e., the heavier germination indicates the less destruction of seed, this arrangement shows also the relative effect of birds and rodents on reforestation by various methods. This assumption, however, is open to serious error, because of the difference in germination due to other factors, such as moisture conservation induced by local cultivation of seed spots, etc.

Table 7 shows the results obtained from sowing Chilgoza pine by the various methods in the fall of 1910:

TABLE 7.—*Results of sowing Chilgoza pine.*

Method.	Area.	Seedlings alive.		Total germination.	
		July, 1911.	October, 1911.	Actual.	Of possible.
					Per cent.
Broadcast, harrowed	Poisoned				
	Unpoisoned	3		3	0.07
Seed spots, mulched	Poisoned	2	1	2	.4
	Unpoisoned				
Seed spots, unmulched	Poisoned		3	3	.6
	Unpoisoned				
Seed spots, screened	do				

The results obtained from sowing Chilgoza-pine seed were so poor that they may be safely left out of consideration in any conclusions drawn from the results of this experiment.

Table 8 shows the germination percentages in the poisoned and unpoisoned areas under the various methods, arranged to show the comparative results of the work at various seasons, and hence the comparative activity of birds and rodents, together with the balance in favor of the poisoned or unpoisoned areas, as the case may be:

TABLE 8.—*Comparison of the activity of birds and rodents in connection with the work at various seasons.*

Method.	Season.	Total germination of possible.		Balance in favor of—	
		Poisoned area.	Unpoisoned area.	Poisoned area.	Unpoisoned area.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Broadcast, harrowed	Fall		2.71		2.71
	Spring	16.93	17.00		.07
Seed spots, mulched	Fall	6.00	10.00		4.60
	Spring	54.10	48.75	3.35	
Seed spots, unmulched	Fall	1.20	4.55		3.35
	Spring	54.10	37.40	16.70	

Table 9 shows the cost of the work in each method, the number of seedlings germinating, and the cost of each seedling for the work of the most successful season—spring—contracted for the poisoned and unpoisoned areas. The total costs are based on seed at $1.30 per

pound, and labor at $2.50 per 8-hour day. In the case of seed-spot work, the results are reduced to the unit of a spot, as the number of spots varied for the different methods:

TABLE 9.—*Comparison of costs.*

Method.	Total germination.		Total cost.		Cost of each seedling.	
	Poisoned.	Unpoisoned.	Poisoned.	Unpoisoned.	Poisoned.	Unpoisoned.
Broadcast	1,353	1,360	$2.76	$1.49	$0.0020	$0.0011
Seed spots:						
Mulched	10.82	9.75	.0339	.0211	.0031	.0022
Unmulched	10.82	7.48	.0339	.0208	.0031	.0028
Screened	.....	16.69	.....	.3659	.....	.0219

Based on the figures given in Table 9, the following arrangement may be made of the various methods in order of their cheapness:

1. Spring, broadcast, unpoisoned.
2. Spring, broadcast, poisoned.
3. Spring, seed spots, mulched, unpoisoned.
4. Spring, seed spots, unmulched, unpoisoned.
5. Spring, seed spots, mulched or unmulched, poisoned.
6. Spring, seed spots, screened, unpoisoned.

The seedlings are obtained by any method more cheaply where there is no expense for poisoning.

CONCLUSIONS.

1. The destruction of seeds by birds and rodents in the plots sown broadcast after harrowing, as evidenced by the total germination, is greater in the poisoned area than in the unpoisoned. No explanation of this result is at hand. The soil moisture was greater in the poisoned area, and the counts were made in the two areas within a few days of each other and by the same man. Thus apparently the scattering of poisoned wheat in connection with broadcast sowing after harrowing has little or no beneficial effect, but, on the other hand, practically doubles the cost of each seedling germinating.

2. Since all other factors are practically identical, it may be assumed that any difference in germination in seed-spot sowing in poisoned and unpoisoned areas is the result of the poisoning. Since in the case of the mulched seed spots the germination was 0.38 per cent greater in the poisoned area and in the unmulched spots 6.63 per cent greater, it is apparently true that poisoning is of some benefit in connection with seed-spot sowing, particularly in unmulched seed spots. Just why seed spots should be benefited and broadcast sowing not benefited is a question which, being unanswered, leaves considerable doubt as to the validity of the conclusion.

3. A fair measure of the actual loss due to birds and rodents in ordinary seed-spot sowing may be obtained from a comparison of the germination in seed spots protected absolutely from depredations by wire baskets and in spots entirely unprotected but identical in all other factors, as covered in Tables 3 and 4. The average germination percentages for all seasons of 14.67 in unprotected spots and 52.02 in screened spots show that 37.35 per cent of the seed in unprotected spots was devoured. The greatest measure of protection was afforded in the spring, this being the time when rodents are most likely to seek unnatural food supplies. It is apparent that poisoning as conducted in this experiment is inadequate as protection against birds and rodents; that it does not afford more than a fifth of the full measure of protection.

4. The average germination of seed sown in mulched seed spots in the unpoisoned area at all three seasons was 20.2 per cent, as against 14.67 per cent in unmulched seed spots, showing that the presence of the mulch protected 5.53 per cent of the seed from being devoured. This is practically as great a percentage as that shown by the difference between the poisoned and unpoisoned areas.

5. The area covered with poisoned wheat in this experiment was a little less than 3 acres, or less than 15 times the area sown which was supposed to be protected by poisoning, and the poisoned and unpoisoned areas were separated from each other by only about 500 feet. The results show that the effect of poisoning was very small, and this was probably due to the small area covered with poisoned wheat. The distance between the two areas was so small that in all probability one was affected as much as the other by the poisoned wheat or the lack of it. It is felt that the only successful method of employing poisoned wheat is to use it in quantities sufficient to absolutely kill every rodent within at least a quarter of a mile of the sown area and to make this area distinctly unpopular to all visiting birds. The result of other work of the writer leads him to the conclusion that the effect of a thorough poisoning of an area continues for at least two or three years after the poisoning is done.

6. The results obtained so far in this experiment indicate that poisoning, at least as conducted in 1910 and 1911, is not financially advantageous, and that it would be better to sow more heavily on unpoisoned areas, allowing for a certain loss by birds and rodents. The cost of the absolute protection afforded by wire screens throws the cost of the plants above what nursery stock would come to and is absolutely prohibitive.

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